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The spectrum of the singly-ionized nitrogen atom

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With 2 plates and 2 figures in the text

SUMMARY

The spectrum of ionized nitrogen has been studied in the region 10547–2077 Å by using a spark-generated high frequency electrodeless discharge and stigmatic concave-grating spectrographs. About 450 spectrum lines, experimentally classified as N II, have been measured. In the vacuum region improved wavelengths for 15 spectrum lines between 1743 Å and 1084 Å have been obtained from some old plates.

Analysis of the new data has given 55 new levels and approximately 200 newly-classified spectrum lines, including the resonance lines, $2s^2 2p^2\,{}^3P_{2,1} - 2s\,2p^3\,{}^5S_2$, at 2142.775 Å and 2139.007 Å. A consistent system of term values has been derived, and accurate wavelengths in the vacuum region have been recalculated from the term system.

The ionization limit has been determined from selected nf series with the result: $2s^2 2p\,{}^2P_{1/2} = (238\,750.5 \pm 1.3)\ \mathrm{cm}^{-1}$.

Introduction

The spectra from ionizing discharges in air or its constituents, nitrogen and oxygen, have been considered since the early days of spectroscopy. Fowler (1924) achieved the first analysis of some multiplets in the spectrum of the singly-ionized nitrogen atom, N II.

The long-wave region of N II has then been investigated rather completely by Fowler & Freeman (1927) and Freeman (1929). However, astrophysicists still needed an extension of laboratory data to the infrared [see e.g. Edlén (1956)]. Moreover, an examination of some questionable N II lines in existing tables revealed wavelength discrepancies that motivated a reobservation of the whole spectrum above 2000 Å.

The extreme ultraviolet region has been explored in detail by Bowen (1927, 1929), Edlén (1934), and Worley (1945). Some additional precision measurements will be quoted below.

The latest description of the term system of N II is due to Edlén (1934, 1936, 1949). Green & Maxwell (1937) have studied the Zeeman effect for the configurations $2s^2\ 2p\ 3s$, $2s^2\ 2p\ 3p$, and $2s^2\ 2p\ 3d$.

Light source

To secure a pure nitrogen spectrum an electrodeless discharge was chosen. A discharge tube of fused quartz was preferred, because impurity lines from C, O, and Si are more persistent in glass tubes. The tube consisted of a cylindrical central part having a length of 12 cm and an inner diameter of 15 mm, conical end parts 3 cm in length, and vitreosil windows 40 mm in diameter, for end-on observation, all parts being fused together. Two side-tubes fused to the conical end pieces were connected through ground joints to a gas-circulating system including liquid-air-cooled traps.

The discharge tube was excited in the oscillating electromagnetic field of a concentric coil 85 mm long and 28 mm in diameter, made of 24 turns of 2.5 mm silvered copper wire. Spark-generated high frequency pulses were efficient for the work on N II. The coil was connected to a glass-insulated cylindrical condenser through a spark gap between brass spheres. With a capacitance of 0.007 μF the period of the circuit was 1.5 μsec. The condenser was charged by a full-wave rectifier with current limiting resistors, fed from a 500 cycle-per-sec supply.

At optimum conditions, a nitrogen pressure of 0.05–0.07 mm Hg and a spark voltage of 24–36 kV, a uniform glow filled the cylindrical part of the discharge tube. By keeping the repetition frequency well below 100 sparks per sec impurity lines from the forced-air-cooled quartz envelope were almost completely suppressed.

Spectrographs

The spectrum between 2000 Å and 9800 Å was photographed with a Jarrell-Ash Wadsworth spectrograph, model JA70-15 m. This spectrograph is equipped with a 21-foot Wood grating, ruled on aluminum with a red blaze in the first order, having 15000 lines per inch, and a total of 80000 lines. The plate factor is about 5 Å/mm in the first order. The region 2700–4700 Å was measured preferably in the second order. The observations were extended above 9800 Å by using a similar spectrograph, constructed by Lidén (1949), having a 21-foot Rowland grating with 10000 lines per inch and a total of 60000 lines, giving a plate factor of about 7.5 Å/mm. Overlapping orders could be separated by a suitable choice of Eastman spectroscopic plates and Chance or Jena glass filters.

Spectrograms

The light source was focused end-on on the slit of the stigmatic spectrograph. The spectrograms show a bright N II spectrum but relatively few N I and N III lines. Molecular bands of N_2, N_2^+, and CN appear on certain long exposures.

Though the adjustment of the nitrogen partial pressure was rather critical, addition of neon up to a partial pressure of 0.07 mm Hg had no influence on the discharge. The admixture of neon and traces of argon and xenon yielded a convenient set of reference lines in the long-wave region. In order to obtain a sufficiently strong reference spectrum in the region below 5852 Å neon was separately excited in the same discharge tube. Alternatively, spectrograms were furnished with iron reference spectra by means of an iron arc in air imaged inside the discharge tube through the back window.

Admission of helium (0.07–0.14 mm Hg) to the discharge brought on enhanced excitation along the axis, especially in the central part of the tube. These spectrograms permit a separation of the nitrogen spectra of different stages of ionization. As shown on Plates *g* and *j*, the N II lines still have nearly the same intensity from end to end, whereas the N I lines are weakened and the N III lines strengthened in the central part. The radial variation is reversed as compared to the usual ring discharge [see e.g. Bloch & Bloch (1935)].

Spectrum lines in the region 10 547–2077 Å

All spectrum lines above 2000 Å experimentally classified as N II are given in Table 1. The descriptive notation is explained in the head of the table. Spectrum lines previously assigned to N II but omitted in this list are believed not to belong to N II.

Table 1. N II, spectrum lines in the region 10 547–2077 Å.

Description of lines:

h = hazy   bl = blended by   m = masked by

A brace connecting two intensity values indicates that the lines were incompletely resolved.

References to previous measurements:

B = Beals (1931)   F = Freeman (1929)   L = Lunt (1924).

All other wavelengths quoted in column 3 are from Fowler & Freeman (1927).

Intensity and shape	λ (air), Å		σ (vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
4	10 546.76		9 478.99	9.01	$4p\ ^1D_2\quad -5s\ ^1P_1$
5 h	10 126.27		9 872.60	2.53	$4f\ G(3\frac{1}{2})_4-5g\ G(4\frac{1}{2})_4$
				2.72	$G(3\frac{1}{2})_4-\quad G(4\frac{1}{2})_5$
4 h	10 118.49		9 880.19	0.15	$G(3\frac{1}{2})_3-\quad G(4\frac{1}{2})_4$
m N I	(10 108.9)		(9 889.6)	90.0	$D(1\frac{1}{2})_2-\quad F(2\frac{1}{2})_3$
m N I	(10 105.1)		(9 893.3)	3.7	$D(1\frac{1}{2})_1-\quad F(2\frac{1}{2})_2$
6 h	10 070.12		9 927.64	7.65	$D(2\frac{1}{2})_2-\quad F(3\frac{1}{2})_3$
7 h	10 065.15		9 932.55	2.34	$D(2\frac{1}{2})_3-\quad F(3\frac{1}{2})_3$
				2.53	$D(2\frac{1}{2})_3-\quad F(3\frac{1}{2})_4$
7 h	10 035.45		9 961.95	1.95	$G(4\frac{1}{2})_4-\quad H(5\frac{1}{2})_5$
8 h	10 023.27		9 974.05	4.03	$G(4\frac{1}{2})_5-\quad H(5\frac{1}{2})_5$
				4.05	$G(4\frac{1}{2})_5-\quad H(5\frac{1}{2})_6$
7 h	9 969.34		10 028.01	8.01	$G(3\frac{1}{2})_4-\quad H(4\frac{1}{2})_5$
6 h	9 961.86		10 035.53	5.53	$G(3\frac{1}{2})_3-\quad H(4\frac{1}{2})_4$
7 h	9 891.09		10 107.34	7.14	$F(3\frac{1}{2})_4-\quad G(4\frac{1}{2})_4$
				7.33	$F(3\frac{1}{2})_4-\quad G(4\frac{1}{2})_5$
				7.45	$F(3\frac{1}{2})_3-\quad G(3\frac{1}{2})_{4,3}$
6 h	9 887.39		10 111.12	1.12	$F(3\frac{1}{2})_3-\quad G(4\frac{1}{2})_4$
5 h	9 868.21		10 130.78	0.78	$F(2\frac{1}{2})_2-\quad G(3\frac{1}{2})_3$
6 h	9 865.41		10 133.65	3.64	$F(2\frac{1}{2})_3-\quad G(3\frac{1}{2})_{4,3}$
3 h	9 794.01		10 207.52	7.48	$4d\ ^1F_3\quad -5f\ G(4\frac{1}{2})_4$
4 h	9 741.43		10 262.62	2.52	$4f\ F(3\frac{1}{2})_4-5g\ H(4\frac{1}{2})_4$
				2.62	$F(3\frac{1}{2})_4-\quad H(4\frac{1}{2})_5$
4 h	9 737.75		10 266.50	6.50	$F(3\frac{1}{2})_3-\quad H(4\frac{1}{2})_4$
1 h	9 722.36		10 282.75	2.57	$F(3\frac{1}{2})_4-\quad F(3\frac{1}{2})_3$
				2.76	$F(3\frac{1}{2})_4-\quad F(3\frac{1}{2})_4$
1 h	9 718.66		10 286.66	6.55	$F(3\frac{1}{2})_3-\quad F(3\frac{1}{2})_3$
				6.74	$F(3\frac{1}{2})_3-\quad F(3\frac{1}{2})_4$
1 h	9 696.77		10 309.88	9.88	$F(2\frac{1}{2})_2-\quad F(3\frac{1}{2})_3$
m N I	(9 694.0)		(10 312.8)	2.74	$F(2\frac{1}{2})_3-\quad F(3\frac{1}{2})_3$
				2.93	$F(2\frac{1}{2})_3-\quad F(3\frac{1}{2})_4$
1 h	9 480.73		10 544.82	4.81	$4d\ ^3P_1\quad -5f\ D(2\frac{1}{2})_2$
1 h	9 453.50		10 575.19	5.18	$^3P_0\quad -\quad D(1\frac{1}{2})_1$

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
3 h	9 442.82		10 587.15	7.05	$4d\ ^3P_2-5f\ \ D(2\frac{1}{2})_3$
1 h	9 439.40		10 590.98	0.98	$^3P_2-\ \ D(2\frac{1}{2})_2$
1 h	9 431.20		10 600.19	0.20	$^3P_1-\ \ D(1\frac{1}{2})_1$
0	9 325.84		10 719.95	20.03	$4p\ ^3S_1-5s\ \ ^3P_1$
3 h	9 281.06		10 771.67	1.67	$4d\ ^3D_3-5f\ \ F(3\frac{1}{2})_4$
1 h	9 266.61		10 788.47	8.46	$^3D_2-\ \ F(2\frac{1}{2})_3$
1 h	9 253.98		10 803.20	3.18	$^3D_2-\ \ F(3\frac{1}{2})_3$
2 h	9 242.02		10 817.18	7.18	$^3D_1-\ \ F(2\frac{1}{2})_2$
2	9 217.10		10 846.42	6.47	$4p\ ^3S_1-5s\ \ ^3P_2$
2 h	9 146.40		10 930.26	0.24	$4d\ ^3D_3-5f\ \ G(3\frac{1}{2})_4$
1 h	9 121.00		10 960.70	0.61	$^3D_2-\ \ G(3\frac{1}{2})_3$
1 h	9 096.17		10 990.62	0.63	$^3D_3-\ \ D(2\frac{1}{2})_3$
0	9 092.93		10 994.53	4.56	$^3D_3-\ \ D(2\frac{1}{2})_2$
1	9 089.45		10 998.75	8.71	$4p\ ^3P_2-5s\ \ ^3P_1$
1	9 069.51		11 022.92	2.93	$^2P_1-\ \ ^3P_0$
0 h	9 063.78		11 029.89	30.20	$4d\ ^3D_2-5f\ \ D(2\frac{1}{2})_2$
1	9 032.04		11 068.66	8.66	$4p\ ^3P_1-5s\ \ ^3P_1$
1	9 010.39		11 095.25	5.21	$^3P_0-\ \ ^3P_1$
4	8 986.15		11 125.18	5.15	$^3P_2-\ \ ^3P_2$
3 h	8 983.28		11 128.74	8.74	$4d\ ^1D_2-5f\ \ F(2\frac{1}{2})_3$
1 h	8 971.36		11 143.52	3.46	$^1D_2-\ \ F(3\frac{1}{2})_3$
1	8 930.04		11 195.08	5.10	$4p\ ^3P_1-5s\ \ ^3P_2$
1 bl band	8 893.32		11 241.30	1.35	$3s'\ ^3P_2-3p'\ ^3S_1$
0	8 855.40		11 289.44	9.57	$^3P_1-\ \ ^3S_1$
1 h	8 846.46		11 300.85	0.89	$4d\ ^1D_2-5f\ \ G(3\frac{1}{2})_3$
2 h	8 819.56		11 335.32	5.38	$^3F_3-\ \ F(3\frac{1}{2})_4$
3 h	8 772.95		11 395.55	5.57	$^3F_2-\ \ F(3\frac{1}{2})_3$
1 h	8 763.39		11 407.97	8.01	$^3F_4-\ \ G(3\frac{1}{2})_4$
6 h	8 710.54		11 477.19	7.19	$^3F_4-\ \ G(4\frac{1}{2})_5$
5	8 699.002		11 492.42	2.43	$4p\ ^3D_2-5s\ \ ^3P_1$
3 h	8 697.79		11 494.01	3.95	$4d\ ^3F_3-5f\ \ G(3\frac{1}{2})_4$
4	8 694.900		11 497.84	7.84	$4p\ ^3D_1-5s\ \ ^3P_0$
5	8 687.430		11 507.72	7.72	$2p'\ ^1P_1-3p\ \ ^1S_0$
7	8 676.076		11 522.78	2.77	$4p\ ^3D_3-5s\ \ ^3P_2$
3	8 660.52		11 543.48	3.57	$^3D_1-\ \ ^3P_1$
3 h	8 653.38		11 553.00	3.00	$4d\ ^3F_2-5f\ \ G(3\frac{1}{2})_3$

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
3 h	8 638.31		11 573.16	3.14	$4d\ ^3F_3-5f\ \ G(4\frac{1}{2})_4$
3	8 604.32		11 618.88	8.87	$4p\ ^3D_2-5s\ \ ^3P_2$
11	8 438.742		11 846.85	6.86	$3p\ ^1S_0-3d\ \ ^1P_1$
4	8 296.205		12 050.39	0.39	$3d\ ^1P_1-4p\ \ ^1P_1$
4	7 897.62		12 658.56	8.56	$4p\ ^1P_1-5s\ \ ^1P_1$
10	7 762.237		12 879.34	9.34	$3p\ ^1D_2-3d\ \ ^1D_2$
2	7 256.53	9.3 F	13 776.89	6.88	$3d\ ^3P_0-4p\ \ ^3D_1$
3	7 215.06	7.0 F	13 856.08	6.09	$^3P_1-\ \ ^3D_2$
2	7 188.20	8.7 F	13 907.86	7.89	$^3P_2-\ \ ^3D_2$
4	7 138.87	9.8 F	14 003.96	3.99	$^3P_2-\ \ ^3D_3$
2	7 014.73	5.3 F	14 251.79	1.79	$^3P_0-\ \ ^3P_1$
2	7 013.98		14 253.30	3.31	$^3P_1-\ \ ^3P_0$
4	6 975.64	6.8 F	14 331.65	1.66	$^3P_2-\ \ ^3P_1$
3	6 966.81	7.6 F	14 349.82	9.81	$^3P_1-\ \ ^3P_2$
5	6 941.752	2.9 F	14 401.61	1.61	$^3P_2-\ \ ^3P_2$
5	6 887.834	8.7 F	14 514.35	4.35	$3p'\,^5S_2-3d'\ ^5P_3$
4	6 869.580	70.8 F	14 552.92	2.92	$^5S_2-\ \ ^5P_2$
3	6 857.030	7.6 F	14 579.55	9.56	$^5S_2-\ \ ^5P_1$
4	6 847.237		14 600.40	0.42	$3d\ ^3P_0-4p\ \ ^3S_1$
6	6 834.094	6.2	14 628.48	8.49	$^3P_1-\ \ ^3S_1$
7	6 809.989	12.26	14 680.26	0.29	$^3P_2-\ \ ^3S_1$
1	6 801.31		14 698.99	8.93	$4s\ ^3P_2-4f\ \ D(2\frac{1}{2})_3$
3	6 634.789		15 067.91	7.91	$4s\ ^3P_2-3s'\ ^3P_1$
7	6 629.795	30.5	15 079.26	9.26	$3d\ ^1D_2-4p\ \ ^1P_1$
5	6 613.622		15 116.13	6.13	$4s\ ^3P_2-3s'\ ^3P_2$
13	6 610.565	0.58	15 123.12	3.13	$3p\ ^1D_2-3d\ \ ^1F_3$
3	6 595.666		15 157.28	7.28	$4s\ ^3P_1-3s'\ ^3P_0$
3	6 564.20		15 229.94	9.94	$3d\ ^1P_1-4p\ \ ^1D_2$
3 bl H I	6 561.78		15 235.56	5.60	$4s\ ^3P_1-3s'\ ^3P_2$
3	6 560.203		15 239.22	9.22	$^3P_0-\ \ ^3P_1$
3	6 554.47		15 252.55	2.56	$3d\ ^3D_2-4p\ \ ^3D_1$
3	6 545.530	5.2	15 273.38	3.36	$^3D_3-\ \ ^3D_2$
4	6 544.162		15 276.57	6.56	$^3D_1-\ \ ^3D_1$
5	6 532.550	3.0	15 303.73	3.70	$^3D_2-\ \ ^3D_2$
2	6 522.39	2.3	15 327.56	7.70	$^3D_1-\ \ ^3D_2$
6	6 504.608	4.9	15 369.47	9.46	$^3D_3-\ \ ^3D_3$

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
2	6 491.79	2.0	15 399.82	9.80	$3d\ {}^3D_2 - 4p\ {}^3D_3$
13	6 482.053	2.07	15 422.95	2.96	$3s\ {}^1P_1 - 3p\ {}^1P_1$
0	6 457.69		15 481.13	1.16	$2p'\,{}^3S_1 - 3p\ {}^3P_1$
1	6 433.45		15 539.46	9.50	${}^3S_1 - \quad {}^3P_2$
2	6 399.16		15 622.73	2.75	$3d\ {}^1D_2 - 4p\ {}^3D_1$
2	6 384.31		15 659.07	9.05	${}^3F_2 - \quad {}^1P_1$
9	6 379.615	9.63	15 670.59	0.59	$3s\ {}^3P_1 - 3p\ {}^1P_1$
5	6 357.569	7.0	15 724.93	4.92	$3d\ {}^3D_1 - 4p\ {}^3P_0$
6	6 356.545		15 727.47	7.47	${}^3D_2 - \quad {}^3P_1$
5	6 346.86	7.1	15 751.47	1.47	${}^3D_1 - \quad {}^3P_1$
7	6 340.569	0.67	15 767.10	7.08	${}^3D_3 - \quad {}^3P_2$
5	6 328.39	8.6	15 797.44	7.42	${}^3D_2 - \quad {}^3P_2$
1	6 318.80		15 821.42	1.42	${}^3D_1 - \quad {}^3P_2$
2	6 285.70		15 904.72	4.75	$3p\ {}^3P_2 - 3d\ {}^3F_3$
6	6 284.322	4.30	15 908.22	8.21	${}^1D_2 - \quad {}^1P_1$
7	6 242.412	2.52	16 015.02	5.02	$3d\ {}^1F_3 - 4p\ {}^1D_2$
0	6 218.67		16 076.17	6.10	${}^3D_2 - \quad {}^3S_1$
0	6 183.68		16 167.12	7.12	$3p'\,{}^3D_3 - 3d'\,{}^5D_3$
7	6 173.313	3.40	16 194.28	4.28	$3d\ {}^3F_3 - 4p\ {}^3D_2$
6	6 170.166	0.16	16 202.53	2.54	${}^3F_2 - \quad {}^3D_1$
8	6 167.755	7.82	16 208.87	8.87	${}^3F_4 - \quad {}^3D_3$
4	6 150.755	0.9	16 253.67	3.68	${}^3F_2 - \quad {}^3D_2$
4	6 136.894	6.9	16 290.38	0.38	${}^3F_3 - \quad {}^3D_3$
3	6 065.00	5.5	16 483.48	3.48	$3p\ {}^3P_1 - 3d\ {}^1D_2$
4	5 960.901	0.93	16 771.34	1.33	${}^3P_2 - \quad {}^3D_1$
5	5 954.276		16 790.00	0.00	$3d\ {}^1P_1 - 4p\ {}^1S_0$
8	5 952.388	2.39	16 795.33	5.33	$3p\ {}^3P_2 - 3d\ {}^3D_2$
12	5 941.653	1.67	16 825.67	5.67	${}^3P_2 - \quad {}^3D_3$
8	5 940.240	0.25	16 829.67	9.67	${}^3P_1 - \quad {}^3D_1$
11	5 931.779	1.79	16 853.68	3.67	${}^3P_1 - \quad {}^3D_2$
9	5 927.811	7.82	16 864.96	4.95	${}^3P_0 - \quad {}^3D_1$
1	5 899.83		16 944.95	4.95	$3s'\,{}^3P_0 - 3p'\,{}^3D_1$
2	5 897.25		16 952.36	2.36	${}^3P_1 - \quad {}^3D_2$
3	5 893.15		16 964.16	4.16	${}^3P_2 - \quad {}^3D_3$
7	5 767.440	7.43	17 333.91	3.89	$3s\ {}^1P_1 - 3p\ {}^3D_1$
8	5 747.296	7.29	17 394.66	4.65	${}^1P_1 - \quad {}^3D_2$
5	5 730.65	0.67	17 445.19	5.17	${}^3P_2 - \quad {}^3D_1$
10	5 710.766	0.76	17 505.93	5.93	${}^3P_2 - \quad {}^3D_2$
10	5 686.213	6.21	17 581.52	1.52	${}^3P_1 - \quad {}^3D_1$

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
14	5 679.562	9.56	17 602.11	2.12	$3s\ ^3P_2-3p\ ^3D_3$
11	5 676.019	6.02	17 613.09	3.10	$^3P_0-\ ^3D_1$
12	5 666.627	6.64	17 642.29	2.28	$^3P_1-\ ^3D_2$
1 h	5 631.72		17 751.64	1.64	$4p\ ^1D_2-6s\ ^1P_1$
3	5 565.25	5.30	17 963.65	3.64	$3s'\ ^5P_3-3p'\ ^5D_2$
4	5 552.67	2.54 F	18 004.36	4.33	$^5P_2-\ ^5D_1$
5	5 551.922	1.95	18 006.78	6.78	$^5P_3-\ ^5D_3$
5	5 543.471	3.49	18 034.23	4.23	$^5P_2-\ ^5D_2$
4	5 540.059	0.16	18 045.34	5.33	$^5P_1-\ ^5D_0$
8	5 535.363	5.39	18 060.64	0.58 0.70	$^5P_1-\ ^5D_1$ $^5P_3-\ ^5D_4$
7	5 530.244	0.27	18 077.36	7.37	$^5P_2-\ ^5D_3$
5	5 526.239	6.26	18 090.46	0.48	$^5P_1-\ ^5D_2$
10	5 495.666	5.70	18 191.10	1.14	$3p\ ^3P_2-3d\ ^3P_2$
1	5 493.22		18 199.20	9.16	$^3S_1-\ ^1D_2$
7	5 480.062	0.10	18 242.90	2.94	$^3P_2-\ ^3P_1$
7	5 478.096	8.13	18 249.45	9.48	$^3P_1-\ ^3P_2$
4	5 475.29		18 258.80	8.81	$3d\ ^1D_2-4p\ ^1D_2$
7	5 462.592	2.62	18 301.24	1.28	$3p\ ^3P_1-3d\ ^3P_1$
7	5 454.221	4.26	18 329.33	9.35	$^3P_1-\ ^3P_0$
7	5 452.083	2.12	18 336.52	6.56	$^3P_0-\ ^3P_1$
1	5 390.68		18 545.37	5.35	$^3S_1-\ ^3D_1$
2	5 383.71	3.82	18 569.39	9.35	$^3S_1-\ ^3D_2$
4	5 351.220	1.21	18 682.13	2.09	$3p'\ ^5P_3-3d'\ ^5P_3$
3	5 340.213	0.20 F	18 720.64	0.66	$^5P_3-\ ^5P_2$
4	5 338.732	8.66 F	18 725.83	5.84	$^5P_2-\ ^5P_3$
1	5 327.76	7.45 F	18 764.41	4.41	$^5P_2-\ ^5P_2$
4	5 320.953	0.96 F	18 788.40	8.38	$^5P_1-\ ^5P_2$
3	5 320.203		18 791.05	1.05	$^5P_2-\ ^5P_1$
2	5 313.419	3.43 F	18 815.04	5.02	$^5P_1-\ ^5P_1$
2	5 260.57	0.60	19 004.07	4.07	$3s'\ ^3P_2-3p'\ ^3P_2$?
0	5 205.11		19 206.53	6.50	$4p\ ^3S_1-6s\ ^3P_1$
1	5 199.48	9.50 F	19 227.34	7.26	$3p'\ ^5D_4-3d'\ ^5F_3$
2	5 191.97		19 255.15	5.17	$^5D_3-\ ^5F_2$
4	5 190.380	0.42	19 261.05	1.05	$^5D_4-\ ^5F_4$
2	5 186.200	6.17 F	19 276.57	6.55	$^5P_3-\ ^5D_2$
4	5 184.964	4.97	19 281.17	0.71 1.18	$^5D_2-\ ^5F_1$ $^5D_3-\ ^5F_3$
4	5 183.200	3.21	19 287.73	7.73	$^5P_3-\ ^5D_3$
4	5 180.352	0.34 F	19 298.33	8.31	$^5D_2-\ ^5F_2$
7	5 179.52	9.50	19 301.81	1.81	$^5D_4-\ ^5F_5$
7	5 179.35		19 302.06	2.09	$^5P_3-\ ^5D_4$
4	5 177.060		19 310.60	0.61	$^5D_1-\ ^5F_1$
2	5 176.563		19 312.46	2.42	$^5P_2-\ ^5D_1$

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
6	5 175.891	5.89	19 314.97	4.97	$3p'\,{}^5D_3-3d'\,{}^5F_4$
4	5 174.463	4.46	19 320.30	0.30	${}^5P_2-\quad{}^5D_2$
5	5 173.386	3.37	19 324.32	4.32	${}^5D_2-\quad{}^5F_3$
3	5 172.970		19 325.87	5.86	${}^5D_0-\quad{}^5F_1$
4	5 172.346	2.32	19 328.20	8.21	${}^5D_1-\quad{}^5F_2$
4 }	5 171.45	1.46	19 331.55	1.48	${}^5P_2-\quad{}^5D_3$
2 }	5 171.30		19 332.12	2.24	${}^5P_1-\quad{}^5D_0$
4	5 170.168	0.08	19 336.35	6.39	${}^5P_1-\quad{}^5D_1$
1	5 168.99		19 340.75	0.73	$4p\ {}^3S_1-6s\ {}^3P_2$
4	5 168.056	8.24	19 344.25	4.27	$3p'\,{}^5P_1-3d'\,{}^5D_2$
5	5 104.437	4.45	19 585.34	5.31	$3p\ {}^1S_0-4s\ {}^1P_1$
1	5 095.58		19 619.38	9.41	$4p\ {}^3P_2-6s\ {}^3P_2$
5	5 073.590	3.60	19 704.42	4.41	$3s\ {}^1P_1-3p\ {}^3S_1$
2	5 046.51		19 810.14	0.04	$4p\ {}^3P_2-3p'\,{}^3S_1$
11	5 045.100	5.098	19 815.69	5.69	$3s\ {}^3P_2-3p\ {}^3S_1$
3	5 040.72	0.76	19 832.90	2.94	$3p\ {}^3D_3-3d\ {}^3F_2$
1	5 028.81		19 879.89	9.99	$4p\ {}^3P_1-3p'\,{}^3S_1$
9	5 025.662	5.665	19 892.33	2.34	$3p\ {}^3D_3-3d\ {}^3F_3$
5	5 023.048	3.11	19 902.68	2.66	$3s'\,{}^5P_3-3p'\,{}^5P_2$
0	5 022.06		19 906.59	6.54	$4p\ {}^3P_0-3p'\,{}^3S_1$
9	5 016.387	6.387	19 929.11	9.13	$3p\ {}^3D_2-3d\ {}^3F_2$
6	5 012.029	2.026	19 946.44	6.41	$3s'\,{}^5P_3-3p'\,{}^5P_3$
5	5 011.30	1.24 F	19 949.34	9.28	${}^5P_2-\quad{}^5P_1$
10	5 010.620	0.620	19 952.04	2.04	$3s\ {}^3P_1-3p\ {}^3S_1$
11	5 007.325	7.316	19 965.17	5.16	$3p\ {}^3S_1-3d\ {}^3P_2$
14	5 005.149	5.140	19 973.85	{3.25 {3.85	$3s'\,{}^5P_2-3p'\,{}^5P_2$ $3p\ {}^3D_3-3d\ {}^3F_4$
0	5 003.88		19 978.90	8.90	$4p\ {}^3D_2-6s\ {}^3P_1$
9	5 002.703	2.692	19 983.62	3.62	$3s\ {}^3P_0-3p\ {}^3S_1$
12	5 001.477	1.469	19 988.52	8.53	$3p\ {}^3D_2-3d\ {}^3F_3$
11	5 001.136	1.128	19 989.88	9.89	${}^3D_1-\quad{}^3F_2$
4	4 997.227	7.23	20 005.52	5.53	$3s'\,{}^5P_1-3p'\,{}^5P_1$

(Table 1, cont.)

Intensity and shape	λ(air), Å		σ(vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
10	4 994.363	4.358	20 016.99	6.96 7.00 7.03	$3p\ ^3S_1-3d\ \ ^3P_1$ $3s'\ ^5P_2-3p'\ ^5P_3$ $4p\ ^3D_3-6s\ \ ^3P_2$
5	4 991.240	1.22	20 029.51	9.50	$3s'\ ^5P_1-3p'\ ^5P_2$
8	4 987.367	7.377	20 045.07	5.03	$3p\ ^3S_1-3d\ \ ^3P_0$
8	4 895.111	5.20	20 422.84	2.82	$2p'\ ^1D_2-3p\ \ ^1P_1$
4	4 860.170	0.35	20 569.66	9.68	$3p\ ^3D_1-3d\ \ ^1D_2$
4	4 810.306	0.286	20 782.89	2.92	$^3D_3-\ \ ^3D_2$
10	4 803.289	3.272	20 813.25	3.26	$^3D_3-\ \ ^3D_3$
4	4 793.650	3.656	20 855.10	5.11	$^3D_2-\ \ ^3D_1$
8	4 788.131	8.126	20 879.14	9.11	$^3D_2-\ \ ^3D_2$
4	4 781.190	1.168	20 909.45	9.45	$^3D_2-\ \ ^3D_3$
7	4 779.722	9.710	20 915.87	5.87	$^3D_1-\ \ ^3D_1$
4	4 774.241	4.222	20 939.88	9.87	$^3D_1-\ \ ^3D_2$
2	4 721.57	1.59	21 173.48	3.44	$3p'\ ^5D_4-3d'\ ^5D_3$
4	4 718.38	8.43	21 187.79	7.80	$^5D_4-\ \ ^5D_4$
2	4 712.07	2.13	21 216.17	6.18	$^5D_3-\ \ ^5D_2$
2	4 709.59	9.45	21 227.34	7.36	$^5D_3-\ \ ^5D_3$
2	4 706.40	6.41	21 241.72	1.72	$^5D_3-\ \ ^5D_4$
2	4 704.24	4.33	21 251.46	1.44	$^5D_2-\ \ ^5D_1$
2	4 702.51	2.57	21 259.31	9.32	$^5D_2-\ \ ^5D_2$
2	4 700.04	0.12	21 270.48	0.50	$^5D_2-\ \ ^5D_3$
1	4 698.55	8.62 F	21 277.19	7.19	$^5D_1-\ \ ^5D_0$
2	4 695.89	5.91	21 289.27	9.22	$^5D_1-\ \ ^5D_2$
6	4 694.637	4.55	21 294.94	4.92	$3d\ ^1P_1-4f\ \ D(2\frac{1}{2})_2$
6	4 678.14	7.93	21 370.01	0.06	$^1P_1-\ \ D(1\frac{1}{2})_2$
5	4 674.909	4.98	21 384.81	4.81	$3s\ ^1P_1-3p\ \ ^3P_0$
5	4 667.206	7.28	21 420.10	0.09	$^1P_1-\ \ ^3P_1$
5	4 654.532	4.57	21 478.42	8.43	$^1P_1-\ \ ^3P_2$
11	4 643.085	3.086 B	21 531.37 B	1.37	$^3P_2-\ \ ^3P_1$
14	4 630.543	0.537 B	21 589.72 B	9.71	$^3P_2-\ \ ^3P_2$
10	4 621.394	1.392 B	21 632.44 B	2.44	$^3P_1-\ \ ^3P_0$
9	4 613.866	3.868 B	21 667.72 B	7.72	$^3P_1-\ \ ^3P_1$
3	4 608.085		21 694.91	4.91	$3d\ ^1F_3-4f\ \ F(2\frac{1}{2})_3$
10	4 607.157	7.153 B	21 699.30 B	9.30	$3s\ ^3P_0-3p\ \ ^3P_1$
3	4 602.53		21 721.10	1.10	$3d\ ^1F_3-4f\ \ F(3\frac{1}{2})_3$
11	4 601.480	1.478 B	21 726.06 B	6.06	$3s\ ^3P_1-3p\ \ ^3P_2$
3	4 564.764	4.78	21 900.80	0.82	$3p\ ^1P_1-3d\ \ ^3F_2$
7	4 552.527	2.536 B	21 959.67	9.69	$3d\ ^1F_3-4f\ \ G(3\frac{1}{2})_4$
9	4 530.410	0.403 B	22 066.87	6.87	$^1F_3-\ \ G(4\frac{1}{2})_4$

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm⁻¹		Combination
	measured	quoted	obs.	calc.	
2	4 508.77		22 172.76	2.70	$3d\ ^3P_2-4f\ \ F(2\frac{1}{2})_3$
6	4 507.557	7.559 B	22 178.75	8.73	$3p\ ^3D_3-3d\ \ ^3P_2$
2	4 488.12	8.15	22 274.79	4.92	$^3D_2-\ \ ^3P_2$
4	4 477.691	7.74	22 326.68	6.72	$^3D_2-\ \ ^3P_1$
2	4 465.527	5.54	22 387.49	7.48	$^3D_1-\ \ ^3P_1$
3	4 459.933	9.96	22 415.57	5.55	$^3D_1-\ \ ^3P_0$
12	4 447.033	7.033 B	22 480.59	0.61	$^1P_1-\ \ ^1D_2$
6	4 442.018	1.99	22 505.97	5.99	$3d\ ^3P_1-4f\ \ D(2\frac{1}{2})_2$
5	4 433.475	3.48	22 549.34	9.34	$^3P_0-\ \ D(1\frac{1}{2})_1$
8	4 432.735	2.739 B	22 553.10	3.10	$^3P_2-\ \ D(2\frac{1}{2})_3$
3	4 431.816	1.82	22 557.78	7.79	$^3P_2-\ \ D(2\frac{1}{2})_2$
4	4 427.964	7.97	22 577.40	7.41	$^3P_1-\ \ D(1\frac{1}{2})_1$
5	4 427.236	7.21	22 581.12	1.13	$^3P_1-\ \ D(1\frac{1}{2})_2$
1	4 417.82		22 629.23	9.21	$^3P_2-\ \ D(1\frac{1}{2})_1$
4	4 417.07		22 633.06	2.93	$^3P_2-\ \ D(1\frac{1}{2})_2$
2	4 374.98	5.00	22 850.83	0.80	$3p\ ^1P_1-3d\ \ ^3D_2$
1	4 247.31		23 537.68	7.79	$^3D_2-\ \ ^1P_1$
1	4 247.20		23 538.27	8.17	$3d\ ^3D_3-4f\ \ F(2\frac{1}{2})_3$
3	4 242.489		23 564.43	4.36	$^3D_3-\ \ F(3\frac{1}{2})_3$
10	4 241.784	1.787 B	23 568.35	8.34 8.51	$^3D_3-\ \ F(3\frac{1}{2})_4$ $^3D_2-\ \ F(2\frac{1}{2})_3$
3	4 241.240		23 571.37	1.37	$^3D_2-\ \ F(2\frac{1}{2})_2$
7	4 237.05	7.049 B	23 594.69 B	4.70	$^3D_2-\ \ F(3\frac{1}{2})_3$
8	4 236.91	6.930 B	23 595.35 B	5.37	$^3D_1-\ \ F(2\frac{1}{2})_2$
8	4 227.743	7.749 B	23 646.62	6.66	$3p\ ^1D_2-4s\ \ ^1P_1$
0	4 209.09		23 751.40	1.60	$3d'\,^5D_4-4f'\ \ ^5F_4$
3	4 207.50	7.51	23 760.41	0.41	$^5D_4-\ \ ^5F_5$
2	4 206.51	6.57	23 766.00	5.96	$^5D_3-\ \ ^5F_4$
1	4 206.11	6.35	23 768.25	8.25	$^5D_2-\ \ ^5F_3$
1	4 201.35		23 795.19	5.33	$3d\ ^3D_3-4f\ \ G(3\frac{1}{2})_3$
5	4 199.980		23 802.93	2.95	$^3D_3-\ \ G(3\frac{1}{2})_4$
3	4 195.974		23 825.66	5.67	$^3D_2-\ \ G(3\frac{1}{2})_3$
2	4 181.10	1.17	23 910.41	0.13	$^3D_3-\ \ G(4\frac{1}{2})_4$
5	4 179.674	9.667 B	23 918.57	8.57	$^3D_3-\ \ D(2\frac{1}{2})_3$
0	4 178.86		23 923.20	3.26	$^3D_3-\ \ D(2\frac{1}{2})_2$
8	4 176.161	6.164 B	23 938.69	8.70	$^1D_2-\ \ F(2\frac{1}{2})_3$
3	4 173.572	3.51	23 953.54	3.60	$^3D_2-\ \ D(2\frac{1}{2})_2$
6	4 171.607	1.608 B	23 964.82	4.89	$^1D_2-\ \ F(3\frac{1}{2})_3$
1	4 169.38		23 977.60	7.60	$^3D_1-\ \ D(2\frac{1}{2})_2$
1	4 161.14	0.8	24 025.08	5.02	$^3D_2-\ \ D(1\frac{1}{2})_1$
2	4 160.50		24 028.80	8.74	$^3D_2-\ \ D(1\frac{1}{2})_2$
3	4 157.01	6.8	24 048.97	9.02	$^3D_1-\ \ D(1\frac{1}{2})_1$
1	4 156.39		24 052.54	2.74	$^3D_1-\ \ D(1\frac{1}{2})_2$
2	4 154.77	5.0	24 061.96	1.96	$3d'\,^5P_3-4f'\ \ ^5D_4$?

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm⁻¹		Combination
	measured	quoted	obs.	calc.	
6	4 145.776	5.764 B	24 114.14	4.15	$3s'\,{}^5P_3-3p'\,{}^5S_2$
5	4 133.672	3.669 B	24 184.74	4.74	${}^5P_2-\quad{}^5S_2$
4	4 131.782		24 195.81	5.86	$3d\,{}^1D_2-4f\quad G(3\tfrac{1}{2})_3$
4	4 124.078	4.081 B	24 241.01	0.99	$3s'\,{}^5P_1-3p'\,{}^5S_2$
0	4 114.36		24 298.26	8.41	$3p\,{}^1P_1-3d\quad{}^3P_1$
2	4 110.83		24 319.11	9.10	$3d\,{}^1D_2-4f\quad D(2\tfrac{1}{2})_3$
3	4 110.04	0.00	24 323.82	3.79	${}^1D_2-\quad D(2\tfrac{1}{2})_2$
m N III	(4 097.3)		(24 399)	8.93	${}^1D_2-\quad D(1\tfrac{1}{2})_2$
0	4 096.58		24 403.73	3.77	${}^3F_4-\quad F(3\tfrac{1}{2})_3$
4	4 095.904		24 407.75	7.75	${}^3F_4-\quad F(3\tfrac{1}{2})_4$
3	4 087.303	7.35	24 459.11	9.09	${}^3F_3-\quad F(2\tfrac{1}{2})_3$
1	4 082.89	2.85	24 485.55	5.28	${}^3F_3-\quad F(3\tfrac{1}{2})_3$
5	4 082.270	2.280 B	24 489.26	9.26	${}^3F_3-\quad F(3\tfrac{1}{2})_4$
3	4 076.908	6.83	24 521.47	1.35	${}^3F_2-\quad F(2\tfrac{1}{2})_2$
6	4 073.042	3.055 B	24 544.74	4.68	${}^3F_2-\quad F(3\tfrac{1}{2})_3$
4	4 056.90	7.00	24 642.40	2.36	${}^3F_4-\quad G(3\tfrac{1}{2})_4$
4	4 044.777	4.75	24 716.26	6.25	${}^3F_3-\quad G(3\tfrac{1}{2})_3$
9	4 043.529	3.537 B	24 723.89	3.87	${}^3F_3-\quad G(3\tfrac{1}{2})_4$
11	4 041.311	1.321 B	24 737.46	7.46	${}^3F_4-\quad G(4\tfrac{1}{2})_5$
2	4 039.345		24 749.50	9.54	${}^3F_4-\quad G(4\tfrac{1}{2})_4$
1	4 037.96		24 758.00	7.98	${}^3F_4-\quad D(2\tfrac{1}{2})_3$
9	4 035.080	5.087 B	24 775.66	5.65	${}^3F_2-\quad G(3\tfrac{1}{2})_3$
7	4 026.075	6.080 B	24 831.07	1.05	${}^3F_3-\quad G(4\tfrac{1}{2})_4$
15	3 994.998	4.996 B	25 024.24 B	4.23	$3s\,{}^1P_1-3p\quad{}^1D_2$
10	3 955.851	5.851 B	25 271.86 B	1.86	${}^3P_1-\quad{}^1D_2$
1	3 941.23	0.88 L	25 365.58	5.58	$3d'\,{}^5F_3-4f'\quad{}^5G_4$
2	3 940.66		25 369.29	9.29	${}^5F_4-\quad{}^5G_5$
4	3 939.57	9.59 L	25 376.32	6.32	${}^5F_5-\quad{}^5G_6$
9	3 918.999	9.005 B	25 509.49	9.48	$3p\,{}^1P_1-3d\quad{}^1P_1$
6	3 856.057	6.07	25 925.87	5.84	$3p\,{}^3P_2-4s\quad{}^3P_1$
5	3 855.100	5.08	25 932.31	2.34	${}^3P_1-\quad{}^3P_0$
5	3 847.409	7.38	25 984.15	4.18	${}^3P_1-\quad{}^3P_1$
5	3 842.183	2.20	26 019.49	9.46	${}^3P_0-\quad{}^3P_1$
8	3 838.374	8.39	26 045.31	5.31	${}^3P_2-\quad{}^3P_2$
6	3 829.793	9.80	26 103.66	3.65	${}^3P_1-\quad{}^3P_2$
2	3 615.858	5.88	27 648.07	8.02	$3p\,{}^3S_1-4s\quad{}^3P_0$
4	3 609.097	9.09	27 699.86	9.86	${}^3S_1-\quad{}^3P_1$
5	3 593.597	3.60	27 819.34	9.33	${}^3S_1-\quad{}^3P_2$
9	3 437.147	7.162	29 085.56	5.58	$3s\,{}^1P_1-3p\quad{}^1S_0$
5	3 408.127	8.136	29 333.21	3.21	${}^3P_1-\quad{}^1S_0$
6	3 331.310	1.32	30 009.59	9.62	$3p\,{}^3D_2-4s\quad{}^3P_1$
5	3 330.314	0.30	30 018.56	8.54	${}^3D_1-\quad{}^3P_0$

(Table 1, cont.)

Intensity and shape	λ(air), Å		σ(vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
5	3 329.704		30 024.06	4.09	$2p'\,^1D_2$–$3p\ ^1D_2$
7	3 328.730	8.79	30 032.85	2.90	$3p\ ^3D_3$–$4s\ ^3P_2$
5	3 324.573	4.58	30 070.40	0.38	$^3D_1$– $^3P_1$
5	3 318.098	8.14	30 129.08	9.09	$^3D_2$– $^3P_2$
2	3 206.709		31 175.61	6.00	$3d\ ^1P_1$–$5f\ D(2\frac{1}{2})_2$
2	3 200.685		31 234.29	4.23	$^1P_1$– $D(1\frac{1}{2})_2$
3 bl band	3 126.40		31 976.4	5.95	$^1F_3$– $G(4\frac{1}{2})_4$
2 bl band	3 086.78		32 386.8	7.07	$^3P_1$– $D(2\frac{1}{2})_2$
2	3 084.155		32 414.37	4.39	$^3P_0$– $D(1\frac{1}{2})_1$
4	3 082.191		32 435.03	4.94	$^3P_2$– $D(2\frac{1}{2})_3$
2	3 081.485		32 442.46	2.46	$^3P_1$– $D(1\frac{1}{2})_1$
2	3 081.222		32 445.23	5.30	$^3P_1$– $D(1\frac{1}{2})_2$
4	3 023.668	3.80	33 062.78	2.78	$3p\ ^1S_0$–$4d\ ^1P_1$
7	3 006.830	6.86	33 247.93	7.93	$3p\ ^1P_1$–$4s\ ^1P_1$
4	2 976.971		33 581.39	1.45	$3d\ ^3D_3$–$5f\ F(3\frac{1}{2})_4$
2 bl band	2 974.65		33 607.6	7.66	$^3D_2$– $F(3\frac{1}{2})_3$
3	2 973.601		33 619.45	9.45	$^3D_1$– $F(2\frac{1}{2})_2$
4	2 962.953		33 740.26	0.02	$^3D_3$– $G(3\frac{1}{2})_4$
4	2 943.495		33 963.28	3.13	$^1D_2$– $F(2\frac{1}{2})_3$
3 bl band	2 942.17		33 978.6	7.85	$^1D_2$– $F(3\frac{1}{2})_3$
3	2 928.655		34 135.38	5.28	$^1D_2$– $G(3\frac{1}{2})_3$
1	2 923.050		34 200.83	0.94	$^1D_2$– $D(2\frac{1}{2})_3$
1 bl band	2 922.76		34 204.3	4.87	$^1D_2$– $D(2\frac{1}{2})_2$
1	2 917.734		34 263.14	3.10	$^1D_2$– $D(1\frac{1}{2})_2$
1	2 904.357		34 420.94	0.86	$^3F_4$– $F(3\frac{1}{2})_4$
1	2 899.086		34 483.52	3.52	$^3F_3$– $F(2\frac{1}{2})_3$
4	2 897.503	7.49	34 502.37	2.37	$^3F_3$– $F(3\frac{1}{2})_4$
1	2 893.889		34 545.45	5.43	$^3F_2$– $F(2\frac{1}{2})_2$
4	2 892.868	2.86	34 557.64	7.64	$^3F_2$– $F(3\frac{1}{2})_3$
3	2 891.046	1.05	34 579.41	9.43	$^3F_4$– $G(3\frac{1}{2})_4$
6	2 885.273	5.25	34 648.61	8.61	$^3F_4$– $G(4\frac{1}{2})_5$
2	2 884.685		34 655.67	5.67	$^3F_3$– $G(3\frac{1}{2})_3$
4	2 884.246	4.25	34 660.94	0.94	$^3F_3$– $G(3\frac{1}{2})_4$
4	2 879.751	9.73	34 715.04	5.07	$^3F_2$– $G(3\frac{1}{2})_3$
4	2 877.681	7.66	34 740.01	0.13	$^3F_3$– $G(4\frac{1}{2})_4$
0 h	2 830.36	30.5	35 320.7	0.7	$3d'\,^5F_3$–$5f'\ ^5G_4$?
				0.7	$^5F_4$– $^5G_5$
1	2 829.358		35 333.32	3.32	$^5F_5$– $^5G_6$
5	2 823.635	3.67	35 404.92	4.97	$2p'\,^1P_1$–$4p\ ^1P_1$
5	2 799.216	9.20	35 713.76	3.73	$3p\ ^1D_2$–$4d\ ^1D_2$
2 h	2 734.702	5.0	36 556.24	5.81	$3p\ ^1S_0$–$5s\ ^1P_1$
				8.2	$3d\ ^1P_1$–$6f\ D(2\frac{1}{2})_2$
1 h	2 731.37		36 600.8	0.6	$3d\ ^1P_1$–$6f\ D(1\frac{1}{2})_2$

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
6	2 709.837	9.82	36 891.66	1.60	$3p\ ^1D_2-4d\ \ ^1F_3$
1 h	2 690.49		37 157.0	6.93	$3d\ ^1F_3-6f\ \ F(3\frac{1}{2})_4$
1 h	2 679.60		37 307.9	8.09	$^1F_3-\ \ G(3\frac{1}{2})_4$
2 h	2 675.78		37 361.2	1.0	$^1F_3-\ \ G(4\frac{1}{2})_4$
0 h	2 646.87		37 769.2	9.2	$^3P_1-\ \ D(2\frac{1}{2})_2$
0 h	2 646.02		37 781.4	1.4	$^3P_0-\ \ D(1\frac{1}{2})_1$
1 h	2 643.93		37 811.2	1.6	$^3P_1-\ \ D(1\frac{1}{2})_2$
2 h	2 643.413		37 818.62	8.62	$^3P_2-\ \ D(2\frac{1}{2})_3$
5	2 590.938	0.91	38 584.52	4.52	$2p'\,^1P_1-4p\ \ ^1D_2$
3 h	2 563.319		39 000.24	0.19	$3d\ ^3D_3-6f\ \ F(3\frac{1}{2})_4$
2 h	2 561.943		39 021.18	1.12	$^3D_2-\ \ F(2\frac{1}{2})_3$
1 h	2 561.545		39 027.24	7.23	$^3D_2-\ \ F(3\frac{1}{2})_3$
3 h	2 560.243		39 047.08	7.08	$^3D_1-\ \ F(2\frac{1}{2})_2$
0	2 558.62		39 071.8	1.74	$3p\ ^3P_2-4d\ \ ^3F_3$
4 h	2 553.422		39 151.39	1.35	$3d\ ^3D_3-6f\ \ G(3\frac{1}{2})_4$
2 h	2 551.64		39 178.7	8.66	$^3D_2-\ \ G(3\frac{1}{2})_3$
3 h	2 537.873		39 391.25	1.31	$^1D_2-\ \ F(2\frac{1}{2})_3$
0 h	2 537.49		39 397.2	7.42	$^1D_2-\ \ F(3\frac{1}{2})_3$
2 h	2 527.762		39 548.80	8.85	$^1D_2-\ \ G(3\frac{1}{2})_3$
0	2 526.17		39 573.7	3.60	$3p\ ^3P_2-4d\ \ ^3D_1$
0 h	2 525.48		39 584.6	4.62	$3d\ ^1D_2-6f\ \ D(2\frac{1}{2})_3$
4	2 524.488	4.55	39 600.09	599.81	$3p\ ^3P_2-4d\ \ ^3D_2$
4	2 522.458	2.51	39 631.95	1.94	$^3P_1-\ \ ^3D_1$
7	2 522.227	2.27	39 635.57	5.45	$^3P_2-\ \ ^3D_3$
6	2 520.791	0.85	39 658.16	8.15	$^3P_1-\ \ ^3D_2$
5	2 520.222	0.27	39 667.11	7.22	$^3P_0-\ \ ^3D_1$
4 h	2 504.188		39 921.07	1.11	$3d\ ^3F_3-6f\ \ F(3\frac{1}{2})_4$
4 h	2 500.672		39 977.20	7.21	$^3F_2-\ \ F(3\frac{1}{2})_3$
2 h	2 499.825		39 990.75	0.76	$^3F_4-\ \ G(3\frac{1}{2})_4$
4 h	2 496.97		40 036.4	6.4	$^3F_4-\ \ G(4\frac{1}{2})_5$
5	2 496.83	6.88	40 038.7	9.03	$3p\ ^3P_2-4d\ \ ^3P_2$
0 h	2 494.92		40 069.4	9.24	$3d\ ^3F_3-6f\ \ G(3\frac{1}{2})_3$
3 h	2 494.71		40 072.7	2.27	$^3F_3-\ \ G(3\frac{1}{2})_4$
3	2 493.940	4.02	40 085.11	5.20	$3p\ ^3P_2-4d\ \ ^3P_1$
2	2 493.16	3.22	40 097.7	7.37	$^3P_1-\ \ ^3P_2$
3 h	2 491.46		40 125.0	5.2	$3d\ ^3F_3-6f\ \ G(4\frac{1}{2})_4$
3 h	2 491.21		40 129.1	8.64	$^3F_2-\ \ G(3\frac{1}{2})_3$
4	2 490.281	0.37	40 144.00	3.54 4.58	$3p\ ^3P_1-4d\ \ ^3P_1$ $2p'\,^1P_1-4p\ \ ^1S_0$

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
3	2 488.746	8.82	40 168.76	8.56	$3p\ {}^3P_1-4d\ {}^3P_0$
2	2 488.120	8.21	40 178.86	8.82	${}^3P_0-\quad {}^3P_1$
0 h	2 461.83		40 607.9	7.9	$3d\ {}^1F_3-7f\ G(4\frac{1}{2})_4$
6	2 461.270	1.30	40 617.14	7.16	$3p\ {}^1D_2-5s\ {}^1P_1$
4	2 390.866	0.90	41 813.12	3.05	$3p\ {}^3S_1-4d\ {}^3P_2$
3	2 388.230	8.24	41 859.25	9.22	${}^3S_1-\quad {}^3P_1$
1	2 386.78	6.80	41 884.7	4.24	${}^3S_1-\quad {}^3P_0$
0 h	2 364.04		42 287.5	7.3	$3d\ {}^3D_2-7f\ F(3\frac{1}{2})_3$
0 h	2 356.90		42 415.6	5.6	${}^3D_3-\quad G(3\frac{1}{2})_4$
2	2 330.855		42 889.56		
3	2 326.340		42 972.79	2.79	$3p\ {}^1S_0-5d\ {}^1P_1$
0	2 325.16		42 994.6	5.01	$3p\ {}^3D_3-4d\ {}^3F_2$
4	2 321.650	1.62 F	43 059.59	9.33	${}^3D_3-\quad {}^3F_3$
4	2 319.941	9.90 F	43 091.30	1.20	${}^3D_2-\quad {}^3F_2$
8	2 317.046	7.01 F	43 145.14	5.27	${}^3D_3-\quad {}^3F_4$
6	2 316.690	6.65 F	43 151.77	1.96	${}^3D_1-\quad {}^3F_2$
7	2 316.493	6.46 F	43 155.44	5.52	${}^3D_2-\quad {}^3F_3$
0 h	2 315.25		43 178.7	8.7	$3d\ {}^3F_3-7f\ F(3\frac{1}{2})_4$
0 h	2 312.13		43 236.9	7.3	${}^3F_2-\quad F(3\frac{1}{2})_3$
1 h	2 309.53		43 285.6	5.6	${}^3F_4-\quad G(4\frac{1}{2})_5$
1	2 303.21		43 404.2	4.07	$3p\ {}^3D_1-4d\ {}^1D_2$
4	2 293.318	3.40	43 591.50	1.46	$3p\ {}^3P_2-5s\ {}^3P_1$
3	2 292.652	2.72	43 604.16	4.07	${}^3P_1-\quad {}^3P_0$
4	2 291.652	1.67	43 623.20	3.04	$3p\ {}^3D_3-4d\ {}^3D_3$
3	2 290.259	0.31	43 649.73	9.80	$3p\ {}^3P_1-5s\ {}^3P_1$
0	2 289.84		43 657.8	7.38	$3p\ {}^3D_2-4d\ {}^3D_1$
5	2 288.444	8.47	43 684.34	3.59 5.08	$3p\ {}^3D_2-4d\ {}^3D_2$ $3p\ {}^3P_0-5s\ {}^3P_1$
6	2 286.689	6.73	43 717.87	7.90 8.14	$3p\ {}^3P_2-5s\ {}^3P_2$ $3p\ {}^3D_1-4d\ {}^3D_1$
4	2 283.652	3.70	43 775.99	6.24	$3p\ {}^3P_1-5s\ {}^3P_2$
4	2 238.974	8.91	44 649.45	9.50	$2p'\,{}^1P_1-4f\ D(2\frac{1}{2})_2$
4	2 235.208	5.18	44 724.68	4.64	${}^1P_1-\quad D(1\frac{1}{2})_2$
0	2 218.41		45 063.2	2.89	$3p\ {}^1P_1-4d\ {}^3F_2$
6	2 206.088	6.10	45 314.98	5.00	${}^1P_1-\quad {}^1D_2$
3	2 203.633	3.72	45 365.44	5.48	$3p\ {}^3S_1-5s\ {}^3P_1$
4	2 197.506	7.58	45 491.93	1.92	${}^3S_1-\quad {}^3P_2$

(Table 1, cont.)

Intensity and shape	λ (air), Å		σ (vac.), cm^{-1}		Combination
	measured	quoted	obs.	calc.	
2 h	2 189.78		45 652.4		
3	2 159.927		46 283.33	3.33	$3p\ ^1D_2–5d\ ^1D_2$
6	2 142.775		46 653.76	3.8	$2p\ ^3P_2–2p'\ ^5S_2$
4	2 139.007		46 735.94	5.9	$^3P_1–\ ^5S_2$
5	2 130.179		46 929.58	9.58	$3p\ ^1D_2–5d\ ^1F_3$
5	2 096.856	6.79	47 675.30	5.24	$3p\ ^3D_2–5s\ ^3P_1$
4	2 096.192	6.16	47 690.40	0.27	$^3D_1–\ ^3P_0$
6	2 095.532	5.47	47 705.42	5.49	$^3D_3–\ ^3P_2$
3	2 094.183	4.12	47 736.14	6.00	$^3D_1–\ ^3P_1$
3	2 091.316	1.20	47 801.58	1.68	$^3D_2–\ ^3P_2$
3	2 079.968		48 062.34	2.30	$2p'\ ^3S_1–4p\ ^3P_1$
4	2 076.944		48 132.32	2.25	$^3S_1–\ ^3P_2$

The estimated intensities are given on a logarithmic scale. They are consistent over limited regions only, since the spectral variation in optical transmission factor and photographic response could not be properly accounted for.

The new wavelengths are weighted means of measurements on two to six spectrograms. A few faint lines have been measured on only one spectrogram. Wavelengths given to three decimal places are probably correct to within ± 0.01 Å. In other cases the error is believed not to exceed 0.04 Å. The reduction of the measurements has been made exclusively with standards in the same diffraction order. Standards were provided by interferometrically determined wavelengths in rare gas spectra [Burns, Adams, & Longwell (1950), Burns & Adams (1953), Meggers & Humphreys (1934)], sometimes smoothed and supplemented by the combination principle, and by the adopted wavelengths for the iron arc in air [(Edlén (1957)]. The region below 2591 Å was covered by means of internal standards by computation of N II wavelengths from the observations in the long-wave region.

The most reliable of previous measurements are quoted in the third column of Table 1. The need of accurate laboratory wavelengths for work on stellar radial velocities inspired the early precision measurements by Clark (1914), including twenty strong N II lines between 4643 Å and 3919 Å. Clark's values were in the main adopted by Fowler and Freeman, but they were later superseded by Beals' accurate grating measurements on thirty N II lines in the same region. Compared to the present list Beals' wavelengths for transitions involving 4*f* levels are on the average 0.005 Å higher, and the mean accidental difference is ± 0.005 Å. Other transitions show no significant systematic deviations, and the mean accidental difference is ± 0.003 Å. The extensions furnished by the present investigation are especially marked in the region above 6000 Å, where 117 lines are now listed as compared to previously 34. The wavelengths for ten of these lines were given to two decimal places by Fowler and Freeman. Their value for the line at 6810 Å is 2.27 Å higher than the new one, but for the other nine lines the mean of the absolute values of the discrepancies is 0.05 Å only. Their remaining twenty-four wavelengths above 6000 Å, which were given to one decimal, are generally too high, the mean discrepancy amounting to +0.8 Å.

The wave-numbers in the fourth column of Table 1 were derived by using Edlén's (1953) table of vacuum corrections. In this calculation wavelength values with three decimals were used even when only two decimals have been retained in column two. The new data have been preferred for all but ten lines, where a possible systematic influence of the light source on Beals' wavelengths is likely to be appreciably less than the accidental errors of measurements. These ten lines are marked B in the wave-number column.

Spectrum lines in the vacuum region

Since nitrogen commonly occurs as an impurity in vacuum-ultraviolet light sources, a finding list for N II may be useful. Table 2 contains calculated vacuum wavelengths derived exclusively from the observations above 2000 Å. They should be reliable to ± 0.003 Å. The observations by Fowler and Freeman are included for comparison.

The deep levels that are responsible for the N II spectrum below 1745 Å depend, however, on vacuum-ultraviolet measurements. All available precision measurements have been collected in Table 3, including all observed N II lines below 1745 Å. The new measurements by Edlén and the author refer to a spark in nitrogen at half an atmosphere pressure. The spectrograms were taken by Edlén at the Massachusetts

Table 2. N II, vacuum wavelengths below 2000 Å calculated by the combination principle from observations above 2000 Å.

References to observational data:
FF = Fowler & Freeman (1927) F = Freeman (1929) P = Pretty (1929).
When observed wavelengths were originally given in standard air they have been converted to wavelengths in vacuum.

Combination	λ_{calc}, Å	λ_{obs}	Combination	λ_{calc}, Å	λ_{obs}
$3p\ {}^1P_1$–$5s\ {}^1P_1$	1991.301	1.64 P	$3s\ {}^3P_1$–$4p\ {}^3P_0$	1844.259	4.4 F
			${}^3P_1$– ${}^3P_1$	1843.357	3.5 F
$3s\ {}^1P_1$–$4p\ {}^1P_1$	1887.404	7.45 FF	${}^3P_0$– ${}^3P_1$	1842.284	2.4 F
${}^3P_1$– ${}^1P_1$	1878.624	8.60 FF	${}^3P_1$– ${}^3P_2$	1840.983	1.1 F
$3s\ {}^1P_1$–$4p\ {}^3D_1$	1868.240	8.21 FF	$3s\ {}^1P_1$–$4p\ {}^3S_1$	1839.931	
${}^1P_1$– ${}^3D_2$	1866.457		${}^3P_2$– ${}^3S_1$	1836.172	6.36 FF
${}^3P_2$– ${}^3D_1$	1864.364		${}^3P_1$– ${}^3S_1$	1831.586	1.78 FF
${}^3P_2$– ${}^3D_2$	1862.588	2.57 FF	${}^3P_0$– ${}^3S_1$	1830.527	0.71 FF
${}^3P_1$– ${}^3D_1$	1859.636				
${}^3P_2$– ${}^3D_3$	1859.260	9.22 FF	$3s\ {}^1P_1$–$4p\ {}^1D_2$	1780.551	
${}^3P_0$– ${}^3D_1$	1858.545	8.47 FF	${}^3P_1$– ${}^1D_2$	1772.735	
${}^3P_1$– ${}^3D_2$	1857.870	7.77 FF			
			$2p'\ {}^3S_1$–$3s'\ {}^3P_0$	1766.079	6.08 FF
$3s\ {}^1P_1$–$4p\ {}^3P_0$	1852.721		${}^3S_1$– ${}^3P_1$	1765.140	5.13 FF
${}^1P_1$– ${}^3P_1$	1851.810		${}^3S_1$– ${}^3P_2$	1763.639	3.63 FF
${}^1P_1$– ${}^3P_2$	1849.414	9.4 F			
${}^3P_2$– ${}^3P_1$	1848.002	8.1 F	$3s\ {}^1P_1$–$4p\ {}^1S_0$	1732.428	
${}^3P_2$– ${}^3P_2$	1845.616	5.7 F	${}^3P_1$– ${}^1S_0$	1725.028	

Table 3. N II, spectrum lines in the region 1745–453 Å.

Combination	λ_{calc}, Å	λ_{obs}, (Intensity)					
		Edlén & Eriksson		Weber & Watson (1936)		Fowler & Freeman (1927)	Bowen & Ingram (1926)
$2p'\,^3P_0-3p\,^3D_1$	1745.256	m N I					
$^3P_2-\ ^3D_1$	1745.076						
$^3P_1-\ ^3D_1$	1745.046						
$^3P_2-\ ^3D_2$	1743.228	3.197 (3)		3.226		3.22	
$^3P_1-\ ^3D_2$	1743.197						
$^3P_2-\ ^3D_3$	1740.310	0.309 (4)		0.320			0.315
$2p'\,^3P_0-3p\,^3S_1$	1675.920	5.920 (1)					
$^3P_2-\ ^3S_1$	1675.755	5.744 (4)		5.759		5.83	
$^3P_1-\ ^3S_1$	1675.726						
$2p'\,^3P_1-3p\,^3P_0$	1629.832					9.86	
$^3P_0-\ ^3P_1$	1629.079					9.02	
$^3P_2-\ ^3P_1$	1628.922						
$^3P_1-\ ^3P_1$	1628.896						
$^3P_2-\ ^3P_2$	1627.376					7.42	
$^3P_1-\ ^3P_2$	1627.349						
$2p'\,^3D_1-3p\,^3D_1$	1346.441	6.44 (0)				6.41	
$^3D_2-\ ^3D_1$	1346.413						
$^3D_1-\ ^3D_2$	1345.340	5.330 (1)		5.311		5.29	
$^3D_2-\ ^3D_2$	1345.313						
$^3D_3-\ ^3D_2$	1345.076						
$^3D_2-\ ^3D_3$	1343.574						
$^3D_3-\ ^3D_3$	1343.338	3.338 (2)				3.37	
							Bowen (1927)
$2p'\,^3D_1-3p\,^3P_0$	1276.800	6.800 (2)					6.74
$^3D_1-\ ^3P_1$	1276.225	6.206 (3)		6.175			6.18
$^3D_2-\ ^3P_1$	1276.201						
$^3D_1-\ ^3P_2$	1275.275	5.247 (1)					
$^3D_2-\ ^3P_2$	1275.251						
$^3D_3-\ ^3P_2$	1275.038	5.038 (4)					5.06
			Wilkinson (1955)		Boyce & Rieke (1935)	Edlén (1934)	
$2p\,^3P_2-2p'\,^3D_3$	1085.701	5.701 (12)	5.707	5.726	5.74	5.699	5.701
$^3P_2-\ ^3D_2$	1085.546	5.542 (9)	5.546	5.546	5.546	5.536	5.540
$^3P_2-\ ^3D_1$	1085.529						
$^3P_1-\ ^3D_2$	1084.580	4.572 (11)	4.579	4.582	4.579	4.568	4.566
$^3P_1-\ ^3D_1$	1084.562						
$^3P_0-\ ^3D_1$	1083.990	3.990 (10)	3.990	3.990	3.991	3.977	3.983
$2p\,^3P_2-2p'\,^3P_1$	916.710				6.708	6.700	6.698
$^3P_2-\ ^3P_2$	916.701						
$^3P_1-\ ^3P_1$	916.020				6.01	6.004	6.018
$^3P_1-\ ^3P_2$	916.012						
$^3P_1-\ ^3P_0$	915.962				5.96	5.955	5.963
$^3P_0-\ ^3P_1$	915.612				5.612	5.603	5.603

(Table 3, cont.)

Combination	λ_{calc}, Å	λ_{obs}, (Intensity)					
		Worley (1945)			Boyce & Rieke (1935)	Edlén (1934)	Bowen (1929)
$2p\ {}^1S_0-3s\ {}^3P_1$	860.205	0.205 (0)					
${}^1S_0-\ {}^1P_1$	858.376	8.374 (1)				8.357	
$2p'\,{}^3D_1-3s'\,{}^3P_0$	836.837	6.837 (1)					
${}^3D_1-\ {}^3P_1$	836.627	6.618 (3)					
${}^3D_2-\ {}^3P_1$	836.616						
${}^3D_1-\ {}^3P_2$	836.289	6.281 (0)					
${}^3D_2-\ {}^3P_2$	836.279						
${}^3D_3-\ {}^3P_2$	836.187	6.184 (3)					
$2p\ {}^1D_2-2p'\,{}^1D_2$	775.965				5.966	5.957	
$2p\ {}^1D_2-3s\ {}^3P_1$	748.369	8.364 (5)					
${}^1D_2-\ {}^1P_1$	746.984	(7)				6.976	6.989

Combination	λ_{calc}, Å	λ_{obs}	
		Edlén (1934)	Bowen (1927, 1929)
$2p\ {}^1S_0-2p'\,{}^1P_1$	745.841	5.836	5.839
$2p\ {}^3P_2-3s\ {}^3P_1$	672.001	1.999	2.026
${}^3P_1-\ {}^3P_0$	671.773	1.770	1.780
${}^3P_1-\ {}^3P_1$	671.630	1.629	1.650
${}^3P_0-\ {}^3P_1$	671.411	1.391	1.397
${}^3P_2-\ {}^3P_2$	671.386		
${}^3P_1-\ {}^3P_2$	671.016	1.014	1.027
$2p\ {}^3P_2-3s\ {}^1P_1$	670.884	0.881	
${}^3P_1-\ {}^1P_1$	670.515	0.508	
${}^3P_0-\ {}^1P_1$	670.296	0.289	
$2p\ {}^1D_2-2p'\,{}^1P_1$	660.286	0.280	0.291
$2p\ {}^3P_2-2p'\,{}^3S_1$	645.178	5.167	5.180
${}^3P_1-\ {}^3S_1$	644.837	4.825	4.836
${}^3P_0-\ {}^3S_1$	644.634	4.621	4.633
$2p\ {}^1S_0-3d\ {}^1P_1$	635.197	5.180	5.20
$2p'\,{}^5S_2-3s'\,{}^5P_1$	629.670		
${}^5S_2-\ {}^5P_2$	629.447	9.434	9.44
${}^5S_2-\ {}^5P_3$	629.167	9.161	9.19
$2p\ {}^1D_2-3d\ {}^1D_2$	582.156	2.150	2.157
${}^1D_2-\ {}^1F_3$	574.650	4.650	
${}^1D_2-\ {}^1P_1$	572.069		
$2p\ {}^1S_0-4d\ {}^1P_1$	559.762	9.760	

Combination	λ_{calc}, Å	λ_{obs}
		Edlén (1934)
$2p\ {}^1D_2-4s\ {}^1P_1$	547.818	7.813
$2p\ {}^3P_2-3d\ {}^3D_2$	533.815	3.809
${}^3P_2-\ {}^3D_3$	533.729	3.726
${}^3P_1-\ {}^3D_1$	533.650	3.644
${}^3P_1-\ {}^3D_2$	533.581	3.577
${}^3P_0-\ {}^3D_1$	533.511	3.504
$2p\ {}^3P_2-3d\ {}^3P_2$	529.867	9.860
${}^3P_2-\ {}^3P_1$	529.722	9.713
${}^3P_1-\ {}^3P_2$	529.637	9.627
${}^3P_1-\ {}^3P_1$	529.491	9.481
${}^3P_1-\ {}^3P_0$	529.413	9.405
${}^3P_0-\ {}^3P_1$	529.355	9.343
$2p\ {}^1D_2-4d\ {}^1D_2$	513.849	3.845
${}^1D_2-\ {}^1F_3$	510.758	0.757
$2p\ {}^3P_2-4s\ {}^3P_1$	509.006	9.018
${}^3P_1-\ {}^3P_0$	508.928	8.903
${}^3P_2-\ {}^3P_2$	508.697	8.700
${}^3P_0-\ {}^3P_1$	508.668	
${}^3P_1-\ {}^3P_2$	508.484	8.459
$2p'\,{}^5S_2-3d'\,{}^5P_3$	506.153	6.160
${}^5S_2-\ {}^5P_2$	506.054	6.057
${}^5S_2-\ {}^5P_1$	505.986	5.985
$2p\ {}^1D_2-5d\ {}^1F_3$	485.849	5.857
$2p\ {}^3P_2-4d\ {}^3D_2$	475.884	5.876
${}^3P_2-\ {}^3D_3$	475.803	5.800

(Table 3, cont.)

Combination	λ_{calc}, Å	λ_{obs}	Combination	λ_{calc}, Å	λ_{obs}
$2p\ {}^3P_1$–$4d\ {}^3D_1$	475.757		$2p\ {}^3P_1$–$4d\ {}^3P_1$	474.602	4.601
${}^3P_1$– ${}^3D_2$	475.698	5.697	${}^3P_1$– ${}^3P_0$	474.546	4.540
${}^3P_0$– ${}^3D_1$	475.647	5.638	${}^3P_0$– ${}^3P_1$	474.493	4.493
$2p\ {}^3P_2$–$4d\ {}^3P_2$	474.891	4.883	$2p\ {}^3P_2$–$5d\ {}^3D_3$	453.	3.340
${}^3P_2$– ${}^3P_1$	474.787	4.774	${}^3P_1$– ${}^3D_2$	453.	3.257
${}^3P_1$– ${}^3P_2$	474.706	4.698			

Table 4. N II, wavelengths of nebular lines.

Combination	λ_{calc}, Å	λ Bowen (1955)	λ Wilson (1950)
$2p\ {}^3P_2$–$2p\ {}^1D_2$	6583.45	6583.37 ± 0.08	6583.43 ± 0.02
$2p\ {}^3P_1$–$2p\ {}^1D_2$	6548.05	6548.06 ± 0.05	6548.06 ± 0.03
$2p\ {}^1D_2$–$2p\ {}^1S_0$	5754.59	5754.57 ± 0.02	

Institute of Technology with the 2-meter normal incidence vacuum spectrograph described by Compton & Boyce (1934). The combinations with the ground term were obtained in absorption in the second order with first order Fe II references. The other measurements were made on reasonably sharp emission lines in the first order. Edlén's (1942) standards in Fe II were supplemented with Cu II : 1358.781, C II : 1334.524, O I : 1302.173, C III : 1247.383, and H I : 1215.670. The smoothed wave-numbers implied in the derived level values (Table 5) should be accurate to ± 0.3 cm^{-1}. This corresponds to an uncertainty in the recalculated wavelengths from 0.009 Å at 1745 Å to 0.0007 Å at 475 Å.

Term analysis

The results of the present analysis are given in Table 5, where the newly-identified levels are indicated by an asterisk. All lines experimentally classified as N II have also been identified with term combinations, except the faint lines at 2330.855 Å and 2189.78 Å. The revised value of $4p\ {}^1S_0$ is based on the fairly strong new line 5954.276 Å and supported by the coincidence at 2490. 281 Å.The identification of the line 5260.57 Å with $3s'\ {}^3P_2$–$3p'\,{}^3P_2$ may be questioned, but no other unidentified line remains in the appropriate region. The alternative classification $4s\,{}^1P_1$–$5p\,{}^1P_1$ is unlikely since no other transitions involving $5p$ levels have been observed. The suggested $4f'$ and $5f'$ levels have been assigned LS symbols from intensity considerations, which, except in the case of ${}^5G_6$, may prove to be invalid in the case of auto-ionization.

Transitions involving electrons with high azimuthal quantum numbers will be especially sensitive to the conditions of excitation because of their sensitivity to external electric fields. The light source chosen made it possible to extend the nf series to higher principal quantum numbers and to reveal the $5g$ levels. These configurations are close to pair coupling [Eriksson (1956)]. Consequently, the multiplicity sign has been replaced with the pair symbol (K) introduced by Racah (1942). The resultant

Table 5. N II, term system.

(New levels are indicated by an asterisk.)

Symbol	Level, cm⁻¹		n^*
$2p\ ^{3}P_{2}$	130.8	*82.1*	
$^{3}P_{1}$	48.7	*48.7*	
$^{3}P_{0}$	0.0		
$^{1}D_{2}$	15 316.2		
$^{1}S_{0}$	32 688.8		
$2p'\ ^{5}S_{2}$	46 784.6		
$^{3}D_{3}$	92 237.2	*−13.1*	
$^{3}D_{2}$	92 250.3	*−1.5*	
$^{3}D_{1}$	92 251.8		
$^{3}P_{2}$	109 217.6	*1.0*	
$^{3}P_{1}$	109 216.6	*−6.9*	
$^{3}P_{0}$	109 223.5		
$^{3}S_{1}$	155 126.73		
$^{1}D_{2}$	144 187.94		
$^{1}P_{1}$	166 765.66		

Limits: $2s^2\ 2p\ ^{2}P_{3/2} = 238\ 924.8_6$
$2s^2\ 2p\ ^{2}P_{1/2} = 238\ 750.5_0$

Symbol	Level, cm⁻¹		n^*
$3s\ ^{3}P_{2}$	149 076.52	*136.35*	2.210261 ($^{2}P_{3/2}$)
$^{3}P_{1}$	148 940.17	*31.58*	
$^{3}P_{0}$	148 908.59		2.210340 ($^{2}P_{1/2}$)
$^{1}P_{1}$	149 187.80		
$4s\ ^{3}P_{2}$	196 711.54	*119.47*	3.224585 ($^{2}P_{3/2}$)
$^{3}P_{1}$	196 592.07	*51.84*	
$^{3}P_{0}$	196 540.23		3.224702 ($^{2}P_{1/2}$)
$^{1}P_{1}$	197 858.69		
$5s\ ^{3}P_{2}$	214 384.13	*126.44*	4.229167 ($^{2}P_{3/2}$)
$^{3}P_{1}$	214 257.69	*45.73*	
$^{3}P_{0}$	214 211.96		4.229356 ($^{2}P_{1/2}$)
$^{1}P_{1}$	214 829.79		
$6s\ ^{3}P_{2}$	*222 878.39	*134.23*	5.23009 ($^{2}P_{3/2}$)
$^{3}P_{1}$	*222 744.16		
$^{1}P_{1}$	*223 101.82		
$3p\ ^{3}D_{3}$	166 678.64	*96.19*	2.464853 ($^{2}P_{3/2}$)
$^{3}D_{2}$	166 582.45	*60.76*	
$^{3}D_{1}$	166 521.69		

Symbol	Level, cm⁻¹		n^*
$3p\ ^{3}P_{2}$	170 666.23	*58.34*	
$^{3}P_{1}$	170 607.89	*35.28*	
$^{3}P_{0}$	170 572.61		
$^{3}S_{1}$	168 892.21		
$^{1}D_{2}$	174 212.03		
$^{1}P_{1}$	164 610.76		
$^{1}S_{0}$	178 273.38		
$4p\ ^{3}D_{3}$	202 861.36	*96.10*	3.488709 ($^{2}P_{3/2}$)
$^{3}D_{2}$	202 765.26	*51.14*	
$^{3}D_{1}$	202 714.12		
$^{3}P_{2}$	203 258.98	*69.95*	
$^{3}P_{1}$	203 189.03	*26.55*	
$^{3}P_{0}$	203 162.48		
$^{3}S_{1}$	203 537.66		
$^{1}D_{2}$	205 350.18		
$^{1}P_{1}$	202 170.63		
$^{1}S_{0}$	*206 910.24		
$3d\ ^{3}F_{4}$	186 652.49	*81.51*	2.897761 ($^{2}P_{3/2}$)
$^{3}F_{3}$	186 570.98	*59.40*	
$^{3}F_{2}$	186 511.58		
$^{3}D_{3}$	187 491.90	*30.34*	
$^{3}D_{2}$	187 461.56	*24.00*	
$^{3}D_{1}$	187 437.56		
$^{3}P_{2}$	188 857.37	*−51.80*	
$^{3}P_{1}$	188 909.17	*−28.07*	
$^{3}P_{0}$	188 937.24		2.963244 ($^{2}P_{3/2}$)
$^{1}F_{3}$	189 335.16		
$^{1}D_{2}$	187 091.37		
$^{1}P_{1}$	190 120.24		
$4d\ ^{3}F_{4}$	209 823.91	*85.94*	3.833694 ($^{2}P_{3/2}$)
$^{3}F_{3}$	209 737.97	*64.32*	
$^{3}F_{2}$	209 673.65		
$^{3}D_{3}$	210 301.68	*35.64*	
$^{3}D_{2}$	210 266.04	*26.21*	
$^{3}D_{1}$	210 239.83		

(Table 5, cont.)

Symbol	Level, cm^{-1}		n^*
4d $^3P_2$	210 705.26	*−46.17*	
$^3P_1$	210 751.43	*−25.02*	
$^3P_0$	210 776.45		3.948860 ($^2P_{3/2}$)
$^1F_3$	211 103.63		
$^1D_2$	209 925.76		
$^1P_1$	211 336.16		
5d $^3D_3$	220 716		
$^1F_3$	221 141.61		
$^1D_2$	*220 495.36		
$^1P_1$	*221 246.17		
4f $G(4\frac{1}{2})_5$	211 389.95	*−12.08*	3.992609 ($^2P_{3/2}$)
$G(4\frac{1}{2})_4$	211 402.03		3.993485 ($^2P_{3/2}$)
$G(3\frac{1}{2})_4$	211 294.85	*7.62*	
$G(3\frac{1}{2})_3$	211 287.23		
$F(3\frac{1}{2})_4$	211 060.24	*3.98*	
$F(3\frac{1}{2})_3$	211 056.26		
$F(2\frac{1}{2})_3$	211 030.07	*−2.86*	
$F(2\frac{1}{2})_2$	211 032.93		
$D(2\frac{1}{2})_3$	211 410.47	*−4.69*	
$D(2\frac{1}{2})_2$	211 415.16		
$D(1\frac{1}{2})_2$	211 490.30	*3.72*	3.999904 ($^2P_{3/2}$)
$D(1\frac{1}{2})_1$	211 486.58		3.999633 ($^2P_{3/2}$)
5f $G(4\frac{1}{2})_5$	221 301.10	*−10.01*	4.990561 ($^2P_{3/2}$)
$G(4\frac{1}{2})_4$	221 311.11		4.991979 ($^2P_{3/2}$)
$G(3\frac{1}{2})_4$	221 231.92	*5.27*	
$G(3\frac{1}{2})_3$	221 226.65		
$F(3\frac{1}{2})_4$	221 073.35	*4.13*	
$F(3\frac{1}{2})_3$	221 069.22		
$F(2\frac{1}{2})_3$	*221 054.50	*−2.51*	
$F(2\frac{1}{2})_2$	*221 057.01		
$D(2\frac{1}{2})_3$	*221 292.31	*−3.93*	
$D(2\frac{1}{2})_2$	*221 296.24		
$D(1\frac{1}{2})_2$	*221 354.47	*2.84*	4.998134 ($^2P_{3/2}$)
$D(1\frac{1}{2})_1$	*221 351.63		4.997 730 ($^2P_{3/2}$)

Symbol	Level, cm^{-1}		n^*
6f $G(4\frac{1}{2})_5$	*226 688.9	*−7.3*	5.98935 ($^2P_{3/2}$)
$G(4\frac{1}{2})_4$	*226 696.2		5.99114 ($^2P_{3/2}$)
$G(3\frac{1}{2})_4$	*226 643.25	*3.03*	
$G(3\frac{1}{2})_3$	*226 640.22		
$F(3\frac{1}{2})_4$	*226 492.09	*3.30*	
$F(3\frac{1}{2})_3$	*226 488.79		
$F(2\frac{1}{2})_3$	*226 482.68	*−1.96*	
$F(2\frac{1}{2})_2$	*226 484.64		
$D(2\frac{1}{2})_3$	*226 675.99	*−2.4*	
$D(2\frac{1}{2})_2$	*226 678.4		
$D(1\frac{1}{2})_2$	*226 720.8	*2.2*	5.99717 ($^2P_{3/2}$)
$D(1\frac{1}{2})_1$	*226 718.6		5.99663 ($^2P_{3/2}$)
7f $G(4\frac{1}{2})_5$	*229 938.1	*−5.0*	6.98871 ($^2P_{3/2}$)
$G(4\frac{1}{2})_4$	*229 943.1		6.99066 ($^2P_{3/2}$)
$G(3\frac{1}{2})_4$	*229 907.5		
$F(3\frac{1}{2})_4$	*229 749.7	*0.8*	
$F(3\frac{1}{2})_3$	*229 748.9		
5g $H(5\frac{1}{2})_6$	*221 364.00	*0.02*	4.999490 ($^2P_{3/2}$)
$H(5\frac{1}{2})_5$	*221 363.98		4.999487 ($^2P_{3/2}$)
$H(4\frac{1}{2})_5$	*221 322.86	*0.10*	
$H(4\frac{1}{2})_4$	*221 322.76		
$G(4\frac{1}{2})_5$	*221 167.57	*0.19*	
$G(4\frac{1}{2})_4$	*221 167.38		
$G(3\frac{1}{2})_4$	*221 163.71	*0.00*	
$G(3\frac{1}{2})_3$	*221 163.71		
$F(3\frac{1}{2})_4$	*221 343.00	*0.19*	
$F(3\frac{1}{2})_3$	*221 342.81		
$F(2\frac{1}{2})$	*221 380.3	Predicted	

Limits: $2s\,2p^2\,{}^4P_{5/2} = 296\,083.6$
$2s\,2p^2\,{}^4P_{3/2} = 296\,002.4$
$2s\,2p^2\,{}^4P_{1/2} = 295\,942.5$

Symbol	Level, cm^{-1}		n^*
3s′ $^5P_3$	205 724.81	*70.59*	2.204009 ($^4P_{5/2}$)
$^5P_2$	205 654.22	*56.25*	
$^5P_1$	205 597.97		
$^3P_2$	211 827.67	*48.22*	
$^3P_1$	211 779.45	*30.10*	
$^3P_0$	211 749.35		2.283286 ($^4P_{1/2}$)

(Table 5, cont.)

Symbol	Level, cm^{-1}		n^*
$3p'\,^5D_4$	223 785.51	*53.92*	2.463969 ($^4P_{5/2}$)
$^5D_3$	223 731.59	*43.14*	
$^5D_2$	223 688.45	*29.90*	
$^5D_1$	223 658.55	*15.25*	
$^5D_0$	223 643.30		
$^5P_3$	225 671.22	*43.75*	
$^5P_2$	225 627.47	*23.97*	
$^5P_1$	225 603.50		
$^5S_2$	229 838.96		
$^3D_3$	*228 791.83	*60.02*	
$^3D_2$	*228 731.81	*37.51*	
$^3D_1$	*228 694.30		
$^3P_2$	*230 831.74?		
$^3S_1$	*223 069.02		
$3d'\,^5F_5$	243 087.32	*40.76*	2.877902 ($^4P_{5/2}$)
$^5F_4$	243 046.56	*33.79*	
$^5F_3$	243 012.77	*26.01*	
$^5F_2$	242 986.76	*17.60*	
$^5F_1$	*242 969.16		
$3d'\,^5D_4$	244 973.31	*14.36*	
$^5D_3$	244 958.95	*11.18*	
$^5D_2$	244 947.77	*7.88*	
$^5D_1$	244 939.89	*4.15*	
$^5D_0$	244 935.74		
$^5P_3$	244 353.31	*−38.57*	
$^5P_2$	244 391.88	*−26.64*	
$^5P_1$	244 418.52		
$4f'\,^5G_6$	*268 463.64	*47.79*	3.993693 ($^4P_{5/2}$)
$^5G_5$	*268 415.85	*37.50*	
$^5G_4$	*268 378.35		
$^5F_5$	*268 733.72	*8.81*	
$^5F_4$	*268 724.91	*8.89*	
$^5F_3$	*268 716.02		
$^5D_4$	*268 415.27?		
$5f'\,^5G_6$	*278 420.64	*53.3*	4.98502 ($^4P_{5/2}$)
$^5G_5$	*278 367.3	*33.8*	
$^5G_4$	*278 333.5?		

azimuthal quantum number L is still significant, though some transitions with $|\Delta L| = 2$ appear with a considerable intensity, viz., $fF(3\frac{1}{2})_{4,3}$–$gH(4\frac{1}{2})_{5,4}$, $d\,^3D_{3,2}$–$fG(3\frac{1}{2})_{4,3}$, and $d\,^1D_2$–$fG(3\frac{1}{2})_3$. The structure in the $3d$ and $4d$ configurations presents also some deviations from LS coupling. The related d levels $^3F_2$, $^1D_2$, and $^3D_2$ give fairly strong intercombination lines. Moreover, the L selection rule is violated by the transitions $p\,^1P_1$–$d\,^3F_2$, $p\,^3P_2$–$d\,^3F_3$, $p\,^3S_1$–$d\,^3D_{2,1}$, and $p\,^3S_1$–$d\,^1D_2$.

A mixing of the nd series with $2p'$ and $4s$ is probably responsible for the appearance of $2p'\,^1P_1$–$4fD(2\frac{1}{2})_2$, $2p'\,^1P_1$–$4fD(1\frac{1}{2})_2$, and $4s\,^3P_2$–$4fD(2\frac{1}{2})_3$. The mutual repulsion between $3d\,^1P_1$ and $2p'\,^1P_1$ has been roughly estimated to ± 450 cm^{-1}. The perturbations from $2p'\,^1P_1$ on the $ns\ ^1P_1$ series are much larger, $3s\,^1P_1$ being depressed more than 2000 cm^{-1}. In this way, the distance between $3s\,^1P_1$ and $3s\,^3P_1$ is reduced to 248 cm^{-1} with accompanying singlet-triplet interaction. The term $3p'\,^3P$ is located immediately above $8s\,^3P$, the term $3p'\,^3D$ somewhat below $7d\,^3D$, which may explain the weakness of lines due to transitions from these terms. On the other hand, owing to the mixing of the even terms $3s'\,^3P$ and $4p\,^3P$, the two-electron jumps $4s\,^3P$–$3s'\,^3P$, $2p'\,^3S$–$4p\,^3P$, and $4p\,^3P$–$3p'\,^3S$ appear with a fair intensity.

Level values

Table 5 contains the complete array of derived level values. The observations in the long-wave region supplied new links connecting the high terms more effectively. The value for $5d\,^3D_3$ still rests on a combination with the ground term only. All other levels, from $2p'\,^3S_1$ upwards have been tied together through spectrum lines above 2000 Å. This group of level values is consistent to within a few units in the last decimal as seen from a comparison of observed and recalculated wave-numbers given in Table 1. Singlets and triplets are well connected. In particular the strong intercombinations with $3s\,^1P_1$ and $3s\,^3P_1$ secure a firm connexion. The attachment of the displaced system—that is, the system based on $2s\,2p^2\,^4P$—has been improved through the observation of $4s\,^3P$–$3s'\,^3P$. The observation of the resonance lines, $2p\,^3P$–$2p'\,^5S$, attached the quintet terms to the main term system. Then, the intercombination $3p'\,^3D_3$–$3d'\,^5D_3$ was identified, fixing the position of the high quintets more exactly.

The six deepest terms, $2p\,^3P$, $2p\,^1D$, $2p\,^1S$, $2p'\,^5S$, $2p'\,^3D$, and $2p'\,^3P$, had to be connected with the remaining term system by means of the vacuum-ultraviolet wavelength measurements compiled in Table 3. The agreement between observed and recalculated wavelengths indicates an uncertainty of about ± 0.3 cm^{-1} in the tabulated level values. The term value for $2p'\,^5S_2$ was derived from the resonance lines at 2142.775 Å and 2139.007 Å, which also gave an accurate value for the interval between $2p\,^3P_2$ and $2p\,^3P_1$. The wavelengths of the forbidden transitions quoted in Table 4 from observations on nebular spectra were also given due weight in fixing the relative positions of the $2p$ levels.

Rydberg denominators

The last column of Table 5 gives the effective quantum numbers, n^*, for those energy levels, E, that have an exactly defined series limit, E_l. They were calculated from the relation

$$n^* = (4R)^{\frac{1}{2}}(E_l - E)^{-\frac{1}{2}}, \tag{1}$$

where $R = 109733.0$ cm^{-1}, the Rydberg constant for nitrogen.

Ionization limit

The theoretical analysis of the observed structure in the $5g$ configuration has given an accurate value of the splitting of the $2s^2 2p\,^2P$ limit, viz. (174.36 ± 0.20) cm^{-1}, [Eriksson (1956)]. The center of gravity of the $2s^2 2p\,^2P$ limit, 238866.74 cm^{-1}, has been determined from the centers of gravity of the three lowest nf configurations by fitting the effective quantum numbers of these centers to a Ritz formula,

$$n^* = n - \alpha + \beta(n^*)^{-2}. \tag{2}$$

The magnitude of the constants, $\alpha = 0.016713$ and $\beta = 0.07796$, indicates that the penetration of the excited electron into the atom core is small and that the simple Ritz formula can be expected to hold accurately. A possible series perturbation from nd' should be insignificant since the configuration $3d'$ is about 6000 cm^{-1} above the ionization limit and presents a quite different coupling. The final result, $2s^2 2p\,^2P_{1/2} = 238750.5$ cm^{-1}, is about 78 cm^{-1} higher than the previously accepted value. The uncertainty in the series limit determination, which is further discussed below, is estimated to ± 1.0 cm^{-1}. To this should be added the uncertainty in the position of the ground level with respect to these series, giving a total error in the ionization limit of ± 1.3 cm^{-1}.

Regularities in the *nf* series

The relative energy levels of the complete nf configurations with $n = 4, 5, 6$, referred to the center of gravity of each configuration, have been plotted in Fig. 1 as a function of n^{-3}. The two series with unique inner quantum numbers, $J = 5$ and $J = 1$, form almost straight lines through the $^2P_{3/2}$ limit. Thus, the electrostatic coupling integrals, responsible for the essential structure, are seen to be nearly proportional to n^{-3}. The same regularity holds for the remaining level series having a unique pair quantum number, $K = 4\frac{1}{2}$ or $K = 1\frac{1}{2}$. On the other hand, there is a considerable repulsion between series with equal K.

An examination of the effective quantum numbers of the individual levels showed that the series with exactly defined parentage in pair coupling obey the Ritz formula (2). In Table 6 is also included the Ritz series representation of the mean values of interacting levels, designated ${}_{\mathrm{Av}}(K)_J$. The agreement between observed and calculated level values, followed up to $7f$ in two cases, indicates that there are no significant

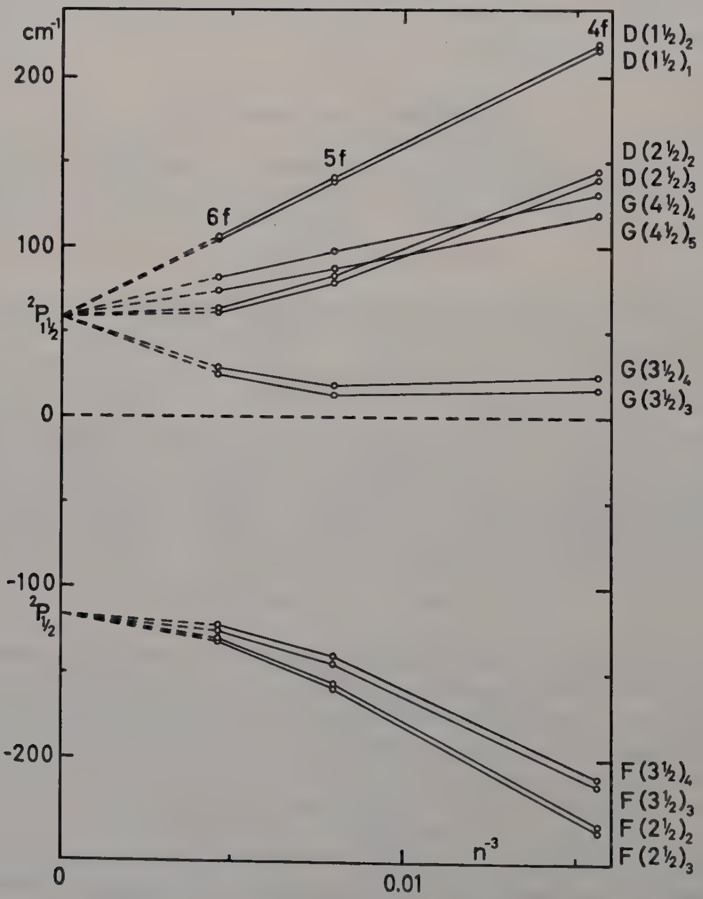

Fig. 1. N II, relative energy levels for nf configurations as a function of n^{-3}.

Table 6. N II, representation of nf series by Ritz formulas: $n^* = n - \alpha + \beta (n^*)^{-2}$.

Limit:	$^2P_{3/2}$				$\frac{1}{2}(^2P_{3/2} + {}^2P_{1/2})$			
Level:	$(4\frac{1}{2})_5$	$(4\frac{1}{2})_4$	$(1\frac{1}{2})_2$	$(1\frac{1}{2})_1$	$_{\mathrm{Av}}(3\frac{1}{2})_4$	$_{\mathrm{Av}}(3\frac{1}{2})_3$	$_{\mathrm{Av}}(2\frac{1}{2})_3$	$_{\mathrm{Av}}(2\frac{1}{2})_2$
$\alpha \times 10^6$	13 081	10 698	5 019	5 660	21 028	22 123	18 373	17 595
$\beta \times 10^5$	9 070	6 671	7 876	8 467	7 282	8 355	7 969	7 167
$E_{\mathrm{obs}} - E_{\mathrm{calc}}$ (cm^{-1}) 4 f	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
5 f	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
6 f	−0.4	−0.1	±0.0	−0.3	+0.1	+0.2	+0.1	±0.0
7 f	−0.2	±0.0						

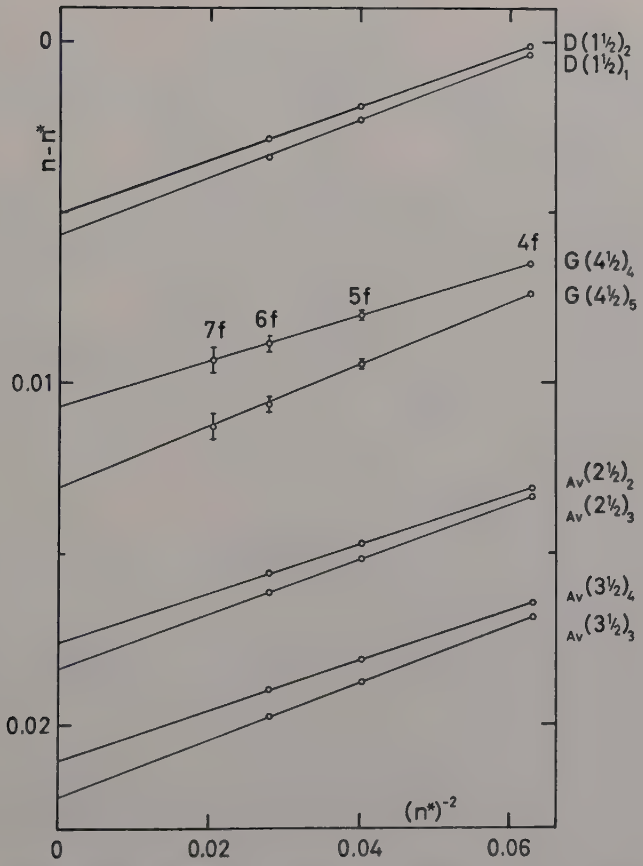

Fig. 2. N II, quantum defect, $n-n^*$, for nf series as a function of $(n^*)^{-2}$. The deviation in $n-n^*$ caused by a change of ±1 cm^{-1} in the limit is indicated for the levels nf $G(4\frac{1}{2})_{5,4}$.

series perturbations. The constants β are small and much the same size. In fact, as seen from Fig. 2, if we disregard the splitting in the pairs, the shift in effective quantum number, $\Delta(n^*)$, from one series to another varies very little with the principal quantum number. Consequently, since according to (1)

$$\Delta(n^*) \approx -(8R)^{-1}(n^*)^3\,\Delta(E_l - E), \tag{3}$$

the differences $\Delta(E_l - E)$ will be approximately proportional to $(n^*)^{-3}$.

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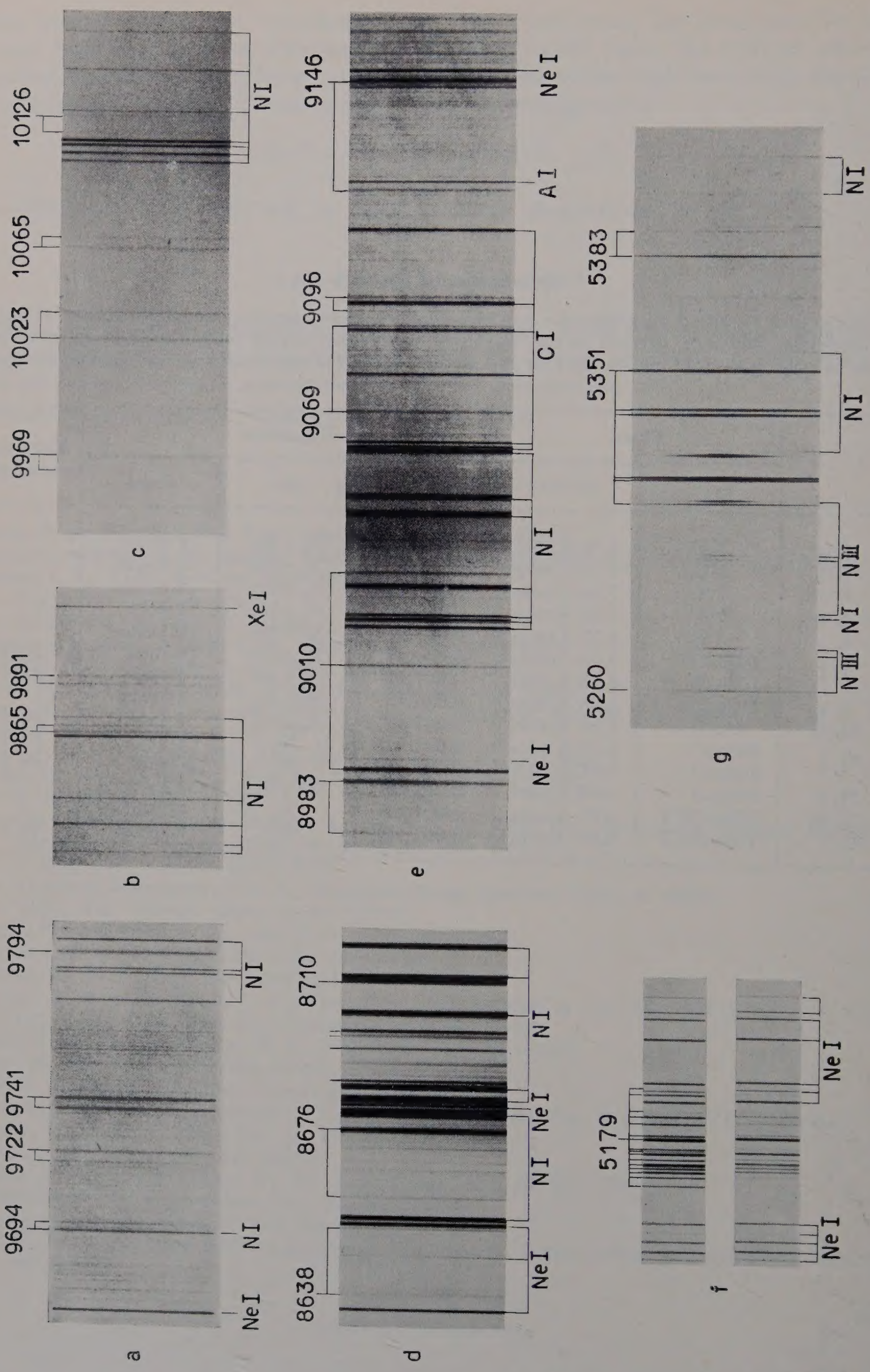
Description of Plates I–II

Spectrograms recorded in stigmatic concave-grating spectrographs, the light source being an electrodeless discharge, excited in the coil of an oscillating circuit with a spark gap of 12 mm. Lines belonging to N II are marked on the upper edge of the spectrograms. Lines of other origins are indicated below the spectrograms.

	Plate		Exposure			External standards
	type	factor	capacitance	gas	time	
I, a	I-M	4.72 Å/mm	0.007 μF	N_2 + Ne	9 hours	
I, b	I-M	7.52 Å/mm	0.007 μF	N_2 + Ne	9 hours	
I, c	I-Z	7.52 Å/mm	0.007 μF	N_2 + Ne	12 hours	
I, d	I-N	4.74 Å/mm	0.007 μF	N_2 + Ne	1 hour	
I, e	I-M	4.73 Å/mm	0.007 μF	N_2 + Ne	9 hours	
I, f	103a-D	4.95 Å/mm	0.007 μF	N_2 + Ne	16 min	Ne I
	103a-D	4.95 Å/mm	0.007 μF	N_2 + Ne	4 min	Ne I
I, g	103a-D	4.95 Å/mm	0.014 μF	He + N_2	1 hour	
II, h	Oa-O	2.39 Å/mm	0.007 μF	N_2 + Ne	4 min	Fe I
II, i	103a-O	2.47 Å/mm	0.007 μF	N_2	6 hours	Fe I
	103a-O	2.47 Å/mm	0.007 μF	N_2	50 min	Fe I
II, j	103a-O	5.04 Å/mm	0.014 μF	He + N_2	1 hour	
II, k	103a-OUV	5.05 Å/mm	0.007 μF	N_2	8 hours	
II, l	103a-OUV	5.05 Å/mm	0.007 μF	N_2	8 hours	Fe I

Plate I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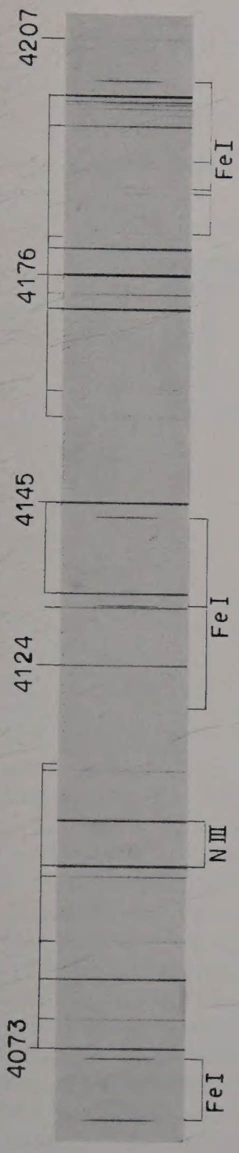
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Fe I
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Fe I

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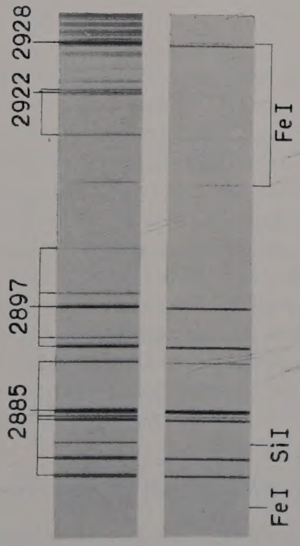
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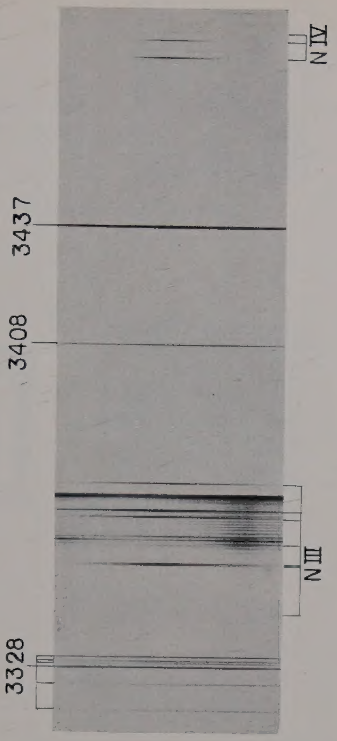
Si I
Fe I

i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N IV
N III

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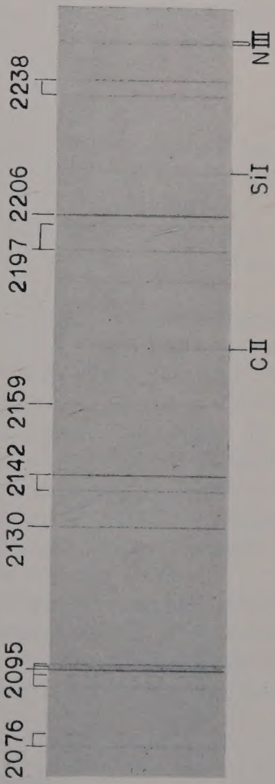
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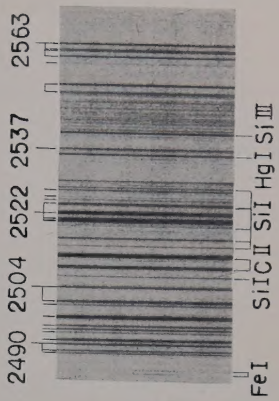
Si I
C II

k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Hg I
Si I
C II
Si I
Fe I

l